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DECEMBER 1953

Society of Motion Picture and Television Engineers

JOURNAL VOL. 61 DECEMBER 1953 NO. 6

Subscription to nonmembers, $12.50 a year; to members, $6.25 a year, included in their annual membership dues; single copies, $1.50. Order from the Society's General Office. A 10% discount is allowed to accredited agencies on orders for subscriptions and single copies. Published monthly at Easton, Pa., by the Society of Motion Picture and Television Engineers, Inc. Publication Office, 20th & Northampton Sts., Easton, Pa. General and Editorial Office, 40 West 40th St., New York 18, N.Y. Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879.

PRINTED BY MACK PRINTING COMPANY, EASTON, PA.

Improved Color Films for Color Motion-Picture Production

By W. T. HANSON, JR., and W. I. KISNER

Negative and positive color films have been made available to the industry in recent years. Several systems are possible for inclusion of special effects when using materials of this type, but the preferred system appears to be that using black-and-white separation positives and a color internegative. Four materials are described which can be used in a system of this type or which can be used in conjunction with existing commercial color motion-picture production processes. Three of these materials represent improvements over earlier products of a similar type which were used in the last few years for a number of motion-picture productions. Formulas and procedures for use with these new films are given and some of the problems associated with printing, process adjustment and control are discussed.

Contents

Presented on April 30, 1953, at the Society's Convention at Los Angeles by W. T. Hanson, Jr., Research Laboratories, Eastman Kodak Co., Rochester 4, N.Y., and W. I. Kisner (who read the paper), Motion Picture Film Dept., Eastman Kodak Co., 343 State St., Rochester 4, N.Y. (This paper was received October 19, 1953.)

I. Introduction

During the past few years, a number of negative and positive color films have been made available to the motion-picture industry. Fully appreciative of the flexibility offered by a negative-positive system from long experience in production of black-and-white pictures, the industry quickly sought ways to utilize these new materials. Some laboratories incorporated the new materials into their existing color processes while others were able to use them in systems of their own design.

In selecting a system for producing color motion pictures, it is well recognized, as in black-and-white work, that it is necessary to employ intermediate steps between the original camera film and the final release print film in order to incorporate the various effects so essential to a finished production. Such steps are also desirable, even when no effects are to be included, to protect the original against possible damage. When the original camera film is an integral-tripack color negative material, there are several possible systems which might be employed. These systems are shown diagrammatically in Figs. 1A through 1D.

The scheme shown in Fig. 1A employs black-and-white films for both positive and negative intermediate stages. The systems shown in Figs. 1B and 1C employ black-and-white materials for only one of the intermediate stages and a color material of the integral-tripack type for the other intermediate stage. In the method shown in Fig. 1D, two color materials of the integral-tripack type are used for the intermediate steps.

While many factors both of technical and economic nature must be considered in choosing a system for production use, there are certain obvious objections to three of the systems shown. The system shown in Fig. 1A is too cumbersome for production use because of the necessity for printing twice from separations. The system shown in Fig. 1B is also unsuitable because of the necessity for making the release prints from separation negatives. The system shown in Fig. 1D has the disadvantage that no protection is provided against loss of the color original or intermediates due to

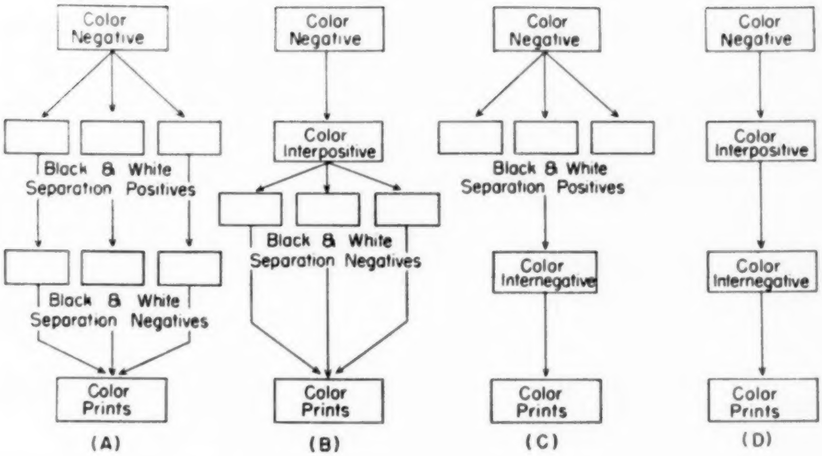

Fig. 1. Systems of color motion-picture production.

possible change of the dye images. Separation positives or negatives would have to be made if such protection were desired. In addition, it is unlikely that adequate reproduction quality could be obtained with such a system at the present time.

The system shown in Fig. 1C overcomes the objections cited for the other systems and appears to be the best suited to production work. Materials suitable for a system of this type are described in this paper.

In 1950, the Eastman Kodak Company provided the industry with a color negative material (Eastman Color Negative Film, Type 5247) and a color print material (Eastman Color Print Film, Type 5381).[1] These films were used together or separately in various commercial processes for production work. In 1951, Eastman Panchromatic Separation Film, Type 5216, and Eastman Color Internegative Film, Type 5243, were introduced.[2] A series of films was then available which could be used together in a system such as that shown in Fig. 1C or which could be used in conjunction with existing commercial color motion-picture production processes. Since that time, numerous color motion-picture productions have been made utilizing one or more of these materials. They have also found extensive use in the preparation of slidefilms and film strips for commercial and educational purposes.

An ever-increasing need has been felt for a color negative material which was sufficiently sensitive and which was correctly balanced for use in the studio with tungsten illumination without the use of filters. Early development work on a product of this type soon indicated that changes could also be made in the characteristics of the color internegative and print films which would result in improved print quality. As a result of this program, three new films have now been made available and appropriate changes have been made in the techniques for handling them to accomplish the desired aims. It is the purpose of this paper to describe these new films, to discuss procedures for exposing and processing them and to indicate some of the problems which may be encountered in their use.

II. Eastman Color Negative Safety Film, Type 5248

General Description

The new color negative film is known as Eastman Color Negative Safety Film, Type 5248. It is a 35mm integral-tripack, incorporated-coupler type film similar in structure to the previous Type 5247 Film, but balanced for use with tungsten (approximately 3200 K), rather than for daylight illumination. It can, of course, be used under daylight conditions or carbon-arc lighting with suitable filters.

The structure of the film is shown in Plate I. It is composed essentially of three emulsions sensitive to blue, green and red light, respectively, and coated on a single safety film support. Between the blue- and green-sensitive layers is a yellow filter layer which prevents blue light from reaching the bottom two emulsion layers, which are also blue-sensitive. The emulsion layers contain dye couplers dispersed within them so that, after exposure and processing, metallic silver and appropriate dye images are produced in each layer. The silver is later removed from the film, leaving the dye images.

As in the case of the earlier Type 5247 Film, two of the couplers dispersed within the emulsion layers are themselves colored. The original color is discharged in proportion to the amount of image dye formed, and the remaining colored coupler serves as a mask to provide correction for unwanted absorption in the process dyes. The characteristics of these colored couplers are similar to those which have been described in previous papers.[1,3]

After processing, the color negative appears as shown in Plate II. Each area of the color negative is complementary in color to the corresponding area in the original scene and, as with other types of negatives, the light and dark tones of the negative are reversed with respect to those of the original subject. In addition to these characteristics, a prominent orange color is observed in all areas of the negative which have received little or no exposure, because of the color-correcting mask remaining in the emulsions.

Characteristics

Eastman Color Negative Film, Type 5248, is balanced for use with 3200 K tungsten illumination. Under these conditions, its speed is slightly less than that of Eastman Background-X Panchromatic Negative Film, Type 5230. Its contrast characteristics are suitable for use with the other materials discussed in this paper. The film is also adaptable for use with color systems employing other films and techniques than those described here. The exposure latitude is somewhat greater than that found for reversal color films. The graininess characteristics of Type 5248 Film are slightly better than those of the earlier Type 5247 Film. The correction for blue-light absorption provided by the colored couplers has also been modified so that blue subjects are not rendered abnormally bright in the reproduction, as was the case with the earlier film. This results in a lower blue-light density for the processed film.

The individual emulsion layers of Eastman Color Negative Film, Type 5248, have keeping properties similar to those of black-and-white negative materials. However, in the case of integral-tripack color films the requirement of maintaining the original color balance must be fulfilled. The storage conditions are therefore slightly more critical than those used for black-and-white negative materials. For extended periods of storage, the film should be kept at temperatures not exceeding 55 F in order to minimize color-balance changes. Regulation of humidity is not important as long as the film remains in the unopened, original, taped can. Ample

Table I. Filters Required With Various Light Sources for Exposure of Eastman Color Negative Film, Type 5248.

Light source	Light source* filter required	Camera filter* required
3200 K Tungsten lamps or "CP" lamps (approx. 3350 K)	None	None
Daylight (sunlight plus some skylight)	None	Kodak Wratten No. 85
M-R Type 170, 150-amp, high-intensity arc	Straw-colored gelatin filter such as Brigham Y-1	Kodak Wratten No. 85
M-R Type 40, 40-amp Duarc	Florentine Glass	Kodak Wratten No. 85

* These are approximate corrections only, since final color-balancing will be done in printing.

time should be allowed for the film to come to equilibrium with the room conditions when the film is removed from storage, and before the tape is removed from the can, in order to prevent condensation of moisture from the atmosphere on the cold film. For a single 1000-ft, 35mm roll, this would generally require about four hours.

Each of the emulsion layers has latent-image keeping properties similar to those found for black-and-white negative films. However, as is the case with emulsion keeping before exposure, the problem is more serious with color films because changes may occur in the exposed film, particularly under storage conditions of high temperature and/or humidity which will result in changes in color balance. It is possible too, that under adverse conditions, the emulsion layers may be affected by the antihalation backing, giving rise to a mottle which will print through to the positive. It is desirable to process the negative film as soon as possible after exposure.

Exposure of Film

Eastman Color Negative Film, Type 5248, is furnished in standard camera lengths for use in conventional black-and-white cameras. It is provided with American Standard negative-type perforations, but which have a shorter pitch dimension.* Camera magazines are loaded in the same manner as for standard black-and-white negative materials.

The camera should be checked photographically for correct focus before starting any production work, because a camera which has been adjusted to obtain critically sharp focus for black-and-white materials may not be adjusted properly for use with color films.

It should also be noted that different types of antireflection coatings cause variations in the color quality of the light transmitted by various camera lenses. In present-day coatings, color variations are usually held within suitable limits. Some of the earlier types of coatings, however, have caused difficulty. It is a good plan to check all lenses photographically, for any variations of this sort, so that they can be interchanged without fear of color-balance shifts.

When 3200 K tungsten illumination is used, no filter is required on the camera or with the light source. It is also possible to use "CP" lamps (approximately 3350 K), since the slight departure in color temperature of these sources from 3200 K can be compensated for in the

* Proposed American Standard PH22.93, 35mm Motion Picture Short-Pitch Negative Film, *Jour. SMPTE, 59:*527, Dec. 1952.

Table II. Illumination (Incident Light) Table for 3200 K Tungsten or "CP" Lamps for Use With Eastman Color Negative Film, Type 5248.
(Shutter speed approximately 1/50 sec; 24 frames/sec)

Lens apertures	$f/2.3$	$f/2.8$	$f/3.5$	$f/4.0$	$f/5.6$
Number of foot-candles required	300	400	600	800	1600

printing operation. The filters required when the film is used with light sources differing considerably in quality from the 3200 K tungsten illumination, are given in Table I.

In lighting a set which is to be photographed on Eastman Color Negative Film, Type 5248, the basic lighting contrast should be fairly soft and the illumination should be distributed evenly. Extremely flat lighting, such as provided by extended front-light sources alone, is undesirable, however, since the results are very uninteresting and lacking in character. Some modeling light can be employed effectively but with lower lighting ratios than those ordinarily used for black-and-white photography. Lighting ratios should not ordinarily be greater than about 3:1, but this will be somewhat dependent upon the range of reflectances encountered in the subject. Where special effects are desired, higher lighting ratios may be used, but experience is required to obtain the exact effect intended.

In addition to the usual footage exposed for the purpose of scene identification (slate shots), it is desirable to expose additional footage to serve as a color-balance reference. It is suggested that a neutral test card or gray scale and suitable color patches be included in the scene. These should be large enough to permit densitometric measurements of the processed negative. This is an invaluable aid in later work involving color-timing and color-printing.

The exposure indexes for use with this film are:

Tungsten – 25 Daylight – 16*

* With Kodak Wratten Filter No. 85.

These values are suitable for use with meters equipped with calculators for ASA Exposure Indexes. The values also apply if the meter reading is taken from a gray card of about 18% reflectance, held close to, and in front of, the subject, facing the camera. For unusually light- or dark-colored subjects, the exposure should be decreased or increased, respectively, from that indicated by the meter. For meters which are equipped for measuring incident light, the data contained in Table II will be useful.

Choice of Costume Colors, Make-Up, Colors for Set Properties, Artwork, etc.

Before starting actual production, it is desirable to make careful tests of various pigments, fabrics, make-up materials, etc., and to determine how these colors will be reproduced in the final print film, using the complete process intended for production. The results of these tests should be evaluated and carefully catalogued for future reference.

Processing

Eastman Color Negative Film, Type 5248, can be processed in conventional-type continuous processing machines, with minor modifications to allow for all of the steps required. The processing steps with approximate times are shown in Table III. The actual processing times will vary somewhat according to the individual processing machine, depending upon the degree of agitation employed, the rate of recirculation, the replenisher rate, etc. The most suitable material for processing machine construction is stainless steel AISI-316. Other materials can, of course, be used for

Table III. Processing Steps for Eastman Color Negative Film, Type 5248.

1.	Prebath	10 sec
2.	Spray rinse	10–20 sec
3.	Color developer	12 min
4.	Spray rinse	10–20 sec
5.	First fixing bath	4 min
6.	Wash	4 min
7.	Bleach	8 min
8.	Wash	8 min
9.	Fix	4 min
10.	Wash	8 min
11.	Wetting agent	5–10 sec
12.	Dry	15–20 min

processing tanks, provided they are lined with hard rubber or lead.

Since the film is sensitive to light of all colors, it must be handled in total darkness through the first fixing or stop bath following color development. The remaining processing operations can be carried out in a lighted room. Where illumination is needed for dials, meters, etc., during color development, a fixture fitted with a Kodak Safelight Filter, Wratten Series 3, may be used, provided such illumination is not incident upon the film itself.

The recommended processing temperature for this film is 70 F. Temperature control equipment should allow for holding the developer solution within plus or minus three-tenths of a degree, the other solutions within one or two degrees, and the wash water within one or two degrees of this value.

In processing the film, the jet antihalation backing must be removed before the film enters the color developer. A solution of the following composition is suitable for this purpose:

Prebath for Jet Backing Removal (Kodak PB-1)

	Avoirdupois—U.S. Liquid		*Metric*
Kodak Borax (sodium tetraborate) ($Na_2B_4O_7 \cdot 10H_2O$)*	20 lb	2 oz 290 grains	20.0 grams
Kodak Sodium Sulfate, desiccated	100 lb	$13\frac{1}{4}$ oz	100.0 grams
Kodalk Balanced Alkali	$6\frac{1}{2}$ lb	375 grains	6.5 grams
Water to make	120 lb	1 gal	1.0 liter

pH (70 F), 9.25 ± 0.05

Specific gravity (70 F), 1.098 ± 0.003

* In case it is desired to use a grade of borax having only 5 moles water of crystallization, the quantity should be reduced to 15 grams per liter. The quantity of Kodalk Balanced Alkali should also be increased to 10 grams per liter to adjust the solution to the proper pH value.

A treatment time of about ten seconds in this solution is sufficient to soften the backing. Longer treatment times may have adverse effects on the sensitometric characteristics. The film is then directed to a side tank containing a buffer wheel, which contacts the base side of the film. This buffer is motor-driven and rotates in a direction counter to and at a peripheral speed of about one-quarter of that of the film itself. The buffer wheel is adjusted so as to exert only a slight pressure on the film, thus minimizing chances of abrasion. Water is continuously supplied to the tank and removed particles are flushed to the sewer. Following the buffing operation, the film is given a brief spray rinse in order to remove any adhering particles of backing, especially those which might have become attached to the emulsion surface.

An efficient squeegee should be provided after this spray rinse to prevent excessive carryover of water to the color developer. The color-developer formula is as follows:

Color Negative Developer (Kodak SD-30)

	Avoirdupois	U.S. Liquid	Metric
Water, about 70–75 F (21–24 C)	96 gal	100 fl oz	800 ml
Benzyl alcohol	58 fl oz	3.9 fl drams	3.8 ml
Kodak Anti-Calcium, sodium metaphosphate, sodium hexametaphosphate or Calgon (Calgon, Inc.)	2 lb	115 grains	2.0 grams
Kodak Sodium Sulfite, desiccated	2 lb	115 grains	2.0 grams
Kodak Sodium Carbonate, monohydrated	50 lb	$6\frac{3}{4}$ oz	50.0 grams
Kodak Potassium Bromide	1 lb	60 grains	1.0 gram
Kodak Sodium Hydroxide, cold 10% solution	84 fl oz	$5\frac{1}{2}$ fl drams	5.5 ml
Kodak Color Developing Agent, CD-3, 4-amino-N-ethyl-N(β-methanesulfonamidoethyl)-*m*-toluidine sesquisulfate monohydrate	5 lb	290 grains	5.0 grams
Water to make	120 gal	1 gal	1.0 liter

pH (70 F), 10.75 ± 0.05

Specific gravity (70 F), 1.046 ± 0.003

In the above formula, the Color Developing Agent, CD-3, is a derivative of *p*-phenylenediamine, which does not normally produce "sensitization" in human skin. Its properties, in this respect, are similar to the well-known Kodak Elon Developing Agent.

An important ingredient of the formula is benzyl alcohol. This material serves as a "developer booster." Increases in benzyl alcohol content cause an increase in speed, contrast and fog level, whereas insufficient amounts tend to produce symptoms of underdevelopment. The effects are not equal for each of the three layers, however. The influence of development time on speed, contrast and fog is, likewise, not equal for the separate layers, nor are the relative effects the same as those obtained by variation of the benzyl alcohol content. Most of the other ingredients of the developer formula serve the same purposes found for black-and-white developers.

Following color development, the film is given a brief spray rinse before it enters the first fixing or stop bath. This minimizes the tendency for formation of carbon dioxide gas and possibility of blistering when the film passes into the acid stop bath. It also helps prolong the life of the latter solution. The formula is as follows:

First Fixing Bath or Stop Bath Formula (Kodak F-5)

	Avoirdupois	U.S. Liquid	Metric
Water, about 125 F (50 C)	72 gal	80 fl oz	600 ml
Kodak Sodium Thiosulfate (Hypo)	240 lb	2 lb	240 grams
Kodak Sodium Sulfite, desiccated	15 lb	2 oz	15.0 grams
Kodak Acetic Acid (28%)	5 gal 80 fl oz	6 fl oz	48 ml
Kodak Boric Acid, crystals	$7\frac{1}{2}$ lb	1 oz	7.5 grams
Kodak Potassium Alum	15 lb	2 oz	15.0 grams
Water to make	120 gal	1 gal	1.0 liter

pH (70 F), 4.25 ± 0.25

Specific gravity (70 F), 1.135 ± 0.003

This solution stops development and provides some hardening of the emulsion. It also converts the unused silver halide salts to complex thiosulfate salts, which can be removed by washing. The pH of the first fixing bath should be controlled within the limits indicated because high pH values result in formation of alum sludge, whereas lower pH values result in less effective hardening.

A water wash is used after the first fixing bath to remove the thiosulfate salts. Spray washing is preferred for this step. An efficient squeegee is also desirable to prevent undue carryover of water into the bleach tank.

The bleach bath is used to convert the metallic silver of the image and also the yellow filter layer to compounds which may later be removed by the second fixing bath. The formula for the bleach solution is as follows:

Bleach for Color Motion Picture Film (Kodak SR-4)

	Avoirdupois	*—U.S. Liquid*	*Metric*
Water, about 70 F (21 C)	96 gal	96 fl oz	800 ml
Kodak Potassium Bromide	20 lb	2 oz 290 grains	20.0 grams
Kodak Potassium Bichromate	5 lb	290 grains	5.0 grams
Kodak Potassium Alum	40 lb	$5\frac{1}{4}$ oz	40.0 grams
Kodak Sodium Acetate*	$2\frac{1}{2}$ lb	145 grains	2.5 grams
Kodak Glacial Acetic Acid*	7 gal 26 fl oz	$7\frac{3}{4}$ fl oz	60.0 ml
Water to make	120 gal	1 gal	1.0 liter

Adjust pH to 3.0 ± 0.20 (70 F) with 10% sodium hydroxide solution
Specific gravity (70 F), 1.038 ± 0.003

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* As a substitute for sodium acetate and glacial acetic acid, either of the following combinations may be used:

	Avoirdupois	*—U.S. Liquid*	*Metric*
Sodium diacetate	42 lb	5 oz 270 grains	42.0 grams
and			
Sulfuric acid, concentrated	123 fl oz	8 fl drams	8.0 ml
or			
Sodium diacetate	42 lb	5 oz 270 grains	42.0 grams
and			
Sodium bisulfate	42 lb	5 oz 270 grains	42.0 grams

It is important to maintain the pH of the solution within the tolerance specified in order to insure efficient bleaching of the silver without bleaching the dye images.

Following the bleach solution, a water wash is used to remove soluble compounds from the film. A spray wash is desirable at this point. A suitable squeegee at the end of the operation is also desirable to prevent excessive carryover to the second fixing bath.

The film must be fixed at this stage. The composition of the second fixing bath is the same as that of the first fixing bath (Kodak F-5). It is not desirable, however, to recirculate the second fixing bath solution with the first fixing bath solution because bleach solution which has been carried over into the second fixing bath may cause stain. It is possible to recirculate the second fixing bath with the general hypo system used for black-and-white processing but proc-

essed film should be carefully inspected for any signs of stain. It is also possible to replenish the second fixing bath by overflow from the first.

A final washing operation follows. Most efficient washing is obtained with a spray wash.

As insurance against drying marks, a final bath containing a wetting agent is used. A number of wetting agents are suitable for this purpose, among which are Kodak Photo-Flo solution, Kreelon, Alkanol-B and Aerosol. A solution containing Kodak Photo-Flo is as follows:

	U.S. Liquid		*Metric*
Water. . .	120 gal	1 gal	1 liter
Kodak Photo-Flo Concentrate.	31 fl oz	2 drams	2.0 ml

If it is desired to use one of the other wetting agents in place of Kodak Photo-Flo solution, tests should be made to determine the optimum concentration. An efficient air squeegee should be used at the end of this operation to remove excess water and to help prevent drying marks.

Film drying conditions ordinarily employed at the present time for use with black-and-white negative films are satisfactory for this film. (Temperature about 70 to 80 F and relative humidity of about 40 to 60%.)

Establishing a Standard Process

With each individual installation, a period of testing is required to arrive at the proper conditions to give satisfactory results. During this initial testing stage, it is important to obtain as much data as possible relative to the mechanical and chemical conditions of the process and the corresponding photographic effects observed.

It is most convenient to record the data graphically, so that the processing conditions can be evaluated quickly and compared with the photographic results. Periodic readings of solution temperatures, flow rates, replenishment rates, machine speed and any other mechanical data can be plotted immediately on charts located in the control room near the processing machine. During the early stages of operation, such readings should be made frequently, say every half hour. When the processing conditions have been stabilized, the frequency of measurements can be reduced but in no case should they be entirely eliminated for routine operation.

In establishing a standard process and for process control, facilities for chemical analysis of the solutions are a requisite. In the early stages of operation, frequent analyses are necessary. In routine operation, such analyses can be made less frequently, according to schedule, unless some unforeseen difficulty occurs which requires detailed investigation. Chemical analysis data are preferably recorded in a graphical manner so as to be quickly available for inspection and comparison with mechanical and sensitometric control data.

Initially, the solutions are made up according to the formulas given above and each solution is checked to see that it has been mixed correctly. After making certain that the solutions have been adjusted to the correct temperature, a series of sensitometric strips is processed, in which the development time is varied over a short range on either side of the nominal time of twelve minutes. From these strips, integral density readings of the neutral scale to red, green and blue light are made and the corresponding characteristic curves are plotted. A time of development is then chosen for which the results are most nearly identical to the manufacturer's standard.

For the solutions other than the developer, the times specified in Table III are satisfactory and no additional changes should be required.

Table IV. Suggested Chemical Control Standards for Important Constituents of Various Processing Solutions for Eastman Color Films.

Solution	Constituent or chemical factor	Control standard
Prebath (Kodak PB-1)	pH (70 F)	9.25 ± 0.10
	Specific gravity (70 F)	1.098 ± 0.003
	Total alkalinity	31.5 ± 2.0
Color negative developer (Kodak SD-30)	Developing Agent CD-3	5.00 ± 0.25 g/l
	Benzyl alcohol	3.8 ± 0.4 g/l
	Sodium sulfite	2.00 ± 0.25 g/l
	Potassium bromide	1.00 ± 0.05 g/l
	pH (70 F)	10.75 ± 0.05
	Specific gravity (70 F)	1.046 ± 0.003
	Total alkalinity	40.0 ± 2.0
Color print developer (Kodak SD-31)	Developing Agent CD-2	3.00 ± 0.25 g/l
	Sodium sulfite	4.0 ± 0.5 g/l
	Potassium bromide	2.00 ± 0.10 g/l
	pH (70 F)	10.65 ± 0.05
	Specific gravity (70 F)	1.023 ± 0.003
	Total alkalinity	37.0 ± 2.0
First and second fixing baths (Kodak F-5)	pH (70 F)	4.25 ± 0.25
	Specific gravity (70 F)	1.135 ± 0.02
	Hypo index	36.0 ± 2.0
Bleach (Kodak SR-4)	Potassium bichromate	5.0 ± 0.5 g/l
	Potassium alum	Not critical
	Potassium bromide	Not critical
	pH (70 F)	3.0 ± 0.2
	Specific gravity (70 F)	1.038 ± 0.003

Process Control

The primary method of control is the adjustment of the mechanical and chemical variables of the process. Mechanical adjustments are made, when required, to keep the machine operating under standard conditions. These include adjustments for temperature, recirculation rate, film speed, etc. Periodic analyses for important constituents of each of the solutions are run and appropriate additions are made to keep the composition of the solutions within specified limits. In this way the process is always restored to a condition which is known to produce satisfactory photographic results. The control limits for each of the important ingredients are determined on the basis of the variations in photographic quality which can be tolerated. This emphasizes the importance of careful correlation of the chemical analysis and photographic data. Suggested limits for the important ingredients of the various solutions are given in Table IV.

To obtain the most uniform results, it is preferable to replenish the solutions continuously during operation rather than by making batch additions at intervals. Replenisher formulas for the various solutions are based on the consumption of the individual ingredients of the solutions as determined from chemical analysis data. The replenisher flow rate is adjusted to keep the composition of the solutions, including the oxidation products, within the appropriate limits. As has been pointed out by Koerner,[4] attempts to compensate for an off-standard chemical condition by changing the operating conditions can result in a process which is completely out of control. Intermittent replenishment fosters this situation.

As a secondary control method, sensitometric procedures are employed. Gray-scale exposures are made in an intensity-scale instrument on the particular emulsion number of the film being used for the picture negative. It is important to use an intensity-scale instrument for these exposures rather than a time-scale instrument, and the instrument should provide an intensity level close to that at which the film is normally exposed in a camera. This is necessary since the reciprocity-law failure characteristics[5] for the separate layers of a multilayer color film are not identical nor are these characteristics the same from one emulsion to another. It is desirable that the color quality of the illumination approximate that for which the film is balanced, tungsten at 3200 K.

The Eastman Processing Control Sensitometer may be used for exposing strips on Type 5248 Film. By operating the lamp at a current of 7.6 amp, a color temperature of approximately 3100 K can be obtained, which is sufficiently close to the recommended color temperature of 3200 K. A Kodak Wratten Neutral Density Filter No. 96, having a density of 1.3, is also required to limit the intensity for proper exposure.

The Herrnfeld Sensitometer* may also be used for making sensitometric exposures on Type 5248 Film, using an appropriate lamp and neutral density filter.

Where no actual sensitometer is available, it is possible to make sensitometric strips on a scene tester, such as the Herrnfeld* or Houston-Fearless† instruments. Sensitometric exposures can also be made in a printer which is provided with a full-frame step tablet made on 35mm black-and-white film. The color balance of the printer is adjusted in this case to give a neutral exposure through the tablet onto Type 5248 Film.

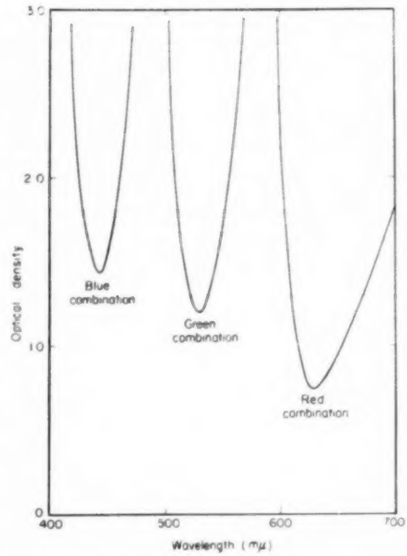


Fig. 2. Spectral density curves for an arbitrary set of filters for measuring red, green and blue densities of color films.

Ordinarily it should be sufficient to make only gray-scale exposures on the negative film for the purpose of measurement. However, a set of tricolor exposures on the same strip of film is useful for rapid visual examination. These can consist of only a few steps through a tablet having a higher gradient than that used for the gray scale. Suitable filters for such tricolor exposures are the Kodak Wratten Filters Nos. 29, 61 and 49. The exposed sensitometric strips are processed along with the picture negative footage. In the processed film, the gray-scale exposure appears brown rather than neutral in color because of the colored coupler mask remaining in the film.

The densities of the processed sensitometric strips might be evaluated in several ways but the most convenient method is to measure the integral density

* Frank Herrnfeld Engineering Co., Culver City, Calif.

† Houston-Fearless Corp., Los Angeles, Calif.

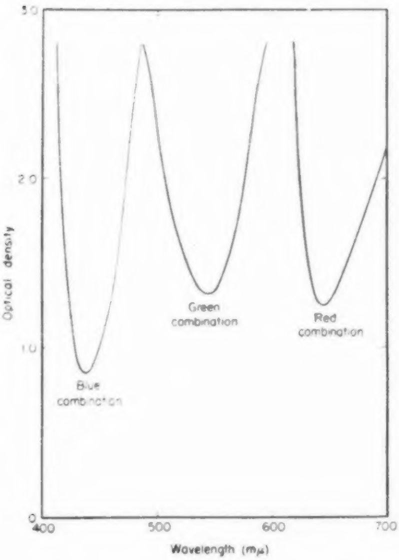


Fig. 3. Spectral density curves for filters designed to read integral densities which approximate effective printing densities of Eastman Color Negative Film and Eastman Color Internegative Film to Eastman Color Print Film.

of each step of the neutral scale to red, green and blue light. It is possible to make such measurements on densitometers equipped with any arbitrary set of tricolor filters such as the Kodak Wratten Filters Nos. 25 (red), 58 (green) and 47 (blue), or filters having specifications similar to those shown in Fig. 2.‡ This type of measurement is useful but has certain limitations.[6] It is better to choose the filters so that the readings represent the densities which the negative film presents to the print film. Typical spectral transmittance curves for the red, green and blue combinations of filters which can be used to measure a close approximation to printing densities of Type 5248 Film with respect to Type 5382 Film are shown in Fig. 3.

During the early stages of operation, it is desirable to plot complete characteristic curves from the integral density readings. Such information is valuable in work of investigational nature in the event of trouble. When a standard process has once been established, several sets of sensitometric strips should be run at intervals, preferably using a check emulsion. These curves should be averaged to give a single set of characteristic curves which should represent the results to be obtained for the standard process level. An idealized set of curves is shown in Fig. 4.

For process control, it is only necessary to read the densities of four steps of the

‡ These filter specifications and those of Fig. 3 are for a densitometer utilizing a tungsten source operating at a color temperature of 3000 K and a photocell having an S-4 type surface.

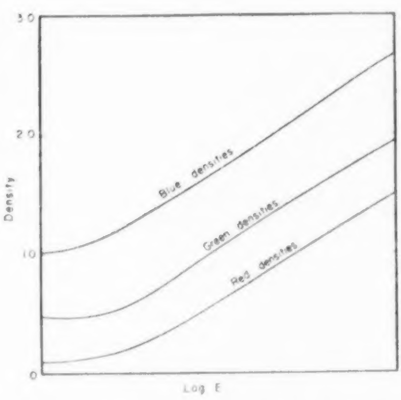


Fig. 4. *D*-log *E* curves for Eastman Color Negative Film, Type 5248.

Exposure, intensity-scale sensitometer, 1/50 sec.

Illumination, tungsten, 3150 K.

Density, effective integral printing density to Eastman Color Print Film, as read with filters shown in Fig. 3.

Densitometer, Eastman Electronic Color Densitometer, Type 31A.

gray scale, one in the toe, a second in the upper toe region, a third at about the middle of the scale and the fourth at the shoulder region of the curve. These densities should be plotted at regular intervals on charts in the control room. It should be recognized that the integral density curves to red, green and blue light do not represent the densities of the individual cyan, magenta and yellow layers, respectively. Each of the dyes has absorptions for regions of the spectrum other than that in which it is primarily intended to absorb. On this account, a change in any one of the process dyes will influence all three curves. The curves should be carefully examined to see which one shows the greatest departure from the standard conditions in attempting to analyze the cause of the processing variations.

Normally, sensitometric test strips are made on the particular emulsion number of film used for the picture negative being processed. The results obtained from such tests represent the combined effect of film and process variations. It is desirable, however, to determine what variation exists in the process itself, independent of the film characteristics and to detect any general drifts in the process from day to day. For this purpose a "check"emulsion may be used. A number of tests are run on several samples of this emulsion to determine its average photographic characteristics so that it will be known what can be expected of this film in a standard process. Every precaution is taken to store the film under good conditions (i.e., at low temperatures, say below 55 F) so as to minimize any changes in its characteristics over a reasonable period of time. Each day, several samples are selected and sensitometric exposures are made on them. The results are averaged and plotted to give the trend curve.

Care of Processed Negative

The processed color negative should be treated with a lacquer on both the emulsion and support sides, immediately after the drying operation. The Eastman Motion Picture Film Lacquer, Bead Type,[7] is satisfactory for this use. The lacquering operation may be carried out in the drying cabinet of the processing machine, using a bead applicator which confines the lacquer coating to the area between the two rows of perforations. This procedure is preferable to lacquering the entire film, because of troubles due to improper film positioning and excessive dirt, which might otherwise occur during the printing operation.

If scratches or abrasions which do not penetrate through the lacquer coating are accidentally put on the film, the lacquer can be removed and a new lacquer coating applied. Eastman Motion Picture Film Lacquer can be removed by treating the film for about two minutes in a 5% sodium carbonate solution, in Kodak Developer D-16 or in any regular black-and-white release positive developer. This treatment must be followed by a water wash, two or three minutes' treatment in an acid stop bath or fixing bath and a final wash. The water wash following the carbonate treatment should not be omitted, otherwise trouble may be experienced in complete removal of the lacquer. The water used for this wash should also be fresh and clean, since only a slight trace of acid may prevent removal of the lacquer. The acid stop bath or fixing bath is necessary to prevent formation of yellow dye in the highlights.

Every effort should be made to provide the best possible storage conditions for the valuable processed color negative in order to prevent damage or deterioration. Since the film has a safety support, no special precautions are required insofar as fire hazard is concerned. High temperature or high relative humidity, however, can cause change of the dyes in processed color films. Relative humidities above 60% promote the growth of molds and cause various physical defects. At very low relative humidities, motion-

picture film may develop excessive curl and brittleness. The best conditions of storage are those where the film can be kept under controlled conditions of temperature and humidity. A relative humidity of 40 to 50% and a temperature of 70 F or less are most satisfactory for storage. Where it is not possible to furnish controlled humidity conditions, the film should be kept in a taped can, care being taken to have the equilibrium humidity of the film below 60% before the can is taped. The best insurance, however, is to prepare black-and-white separation positives in the manner described in a later section of this paper.

III. Eastman Color Print Safety Film, Type 5382 (35mm) and 7382 (16mm)

General Description

The new release print material is known as Eastman Color Print Safety Film, Type 5382 (35mm) and 7382 (16mm). This material is an integral-tripack, incorporated-coupler type film. Prints can be prepared on this film directly from a color negative made on Eastman Color Negative Film, Type 5248, or from Eastman Color Internegative Film, Type 5245. It may also be used for making prints from three-color separation negatives obtained in various ways.

This film is composed essentially of three emulsions sensitized to blue, green and red light and coated on one side of a single safety film support. The emulsions contain, in addition to the silver halide salts, appropriate dye couplers dispersed within them. On exposure and processing, a silver image and a dye image are produced in each layer, according to the exposure which each layer has received. The silver is later removed, leaving only the dye images as the final result in the picture area. The sound-track area, however, is redeveloped to give both a silver and a dye image in the track.

The structure of Eastman Color Print Film is shown diagrammatically in Plate III. The top layer is a gelatin overcoating to minimize the effects of abrasion during the handling of the film. The second layer consists of a green-sensitive emulsion in which is dispersed an uncolored coupler, which, during development, produces a magenta dye image. A gelatin interlayer separates the two top emulsion layers. The fourth layer consists of a red-sensitive emulsion containing a colorless coupler dispersed within it, which, during development, produces a cyan dye image. The fifth layer is a gelatin interlayer. The bottom layer is a blue-sensitive emulsion containing a colorless coupler which, during development, produces a yellow dye. All three emulsion layers are initially tinted purplish-blue in order to reduce light scatter and to improve sharpness. This color disappears during processing. On the side of the support opposite the emulsion layers is a removable jet antihalation backing.

Characteristics

Type 5382 Film is supplied in lengths of 1000 ft and is perforated according to the American Standard PH22.1-1953.* The 16mm film is supplied in lengths of 1,200 ft, perforated according to Proposed American Standards PH22.5 and PH22.12.†

Eastman Color Print Film is color-balanced to allow printing to be done by tungsten-quality illumination having a

* Dimensions for 35mm Motion-Picture Film, Alternate Standards for Either Positive or Negative Raw Stock, PH22.1-1953, *Jour. SMPTE, 60:* 67–68, Jan. 1953.

† Dimensions for 16mm Single-Perforated Motion Picture Film, PH22.12, and Dimensions for 16mm Double-Perforated Motion Picture Film, PH22.5, *Jour. SMPTE, 59:* 527, Dec. 1952.

color temperature of around 3000 K, with appropriate filter systems in the printing beam. The contrast characteristics are such as to give good tone reproduction when prints are made from color negatives made on either Eastman Color Negative Film, Type 5248, or Color Internegative Film, Type 5245.

A new magenta coupler is used in Type 5382 Film which results in an improvement in the reproduction of red hues, as compared with their reproduction with the earlier Type 5381 Film. The sharpness characteristics of the new print film are also noticeably better than those of the earlier material.

Changes in the sensitometric properties of each of the emulsion layers of this film may occur if the film is stored before exposure under adverse conditions of temperature and humidity. The problem is somewhat more serious with this material than with the color negative and the storage conditions are somewhat more critical. Eastman Color Print Film may be stored for periods up to three months at temperatures not exceeding 50 F without significant changes in properties. The lower the temperature at which the film is held, however, the slower will be the rate of change in properties during aging.

Eastman Color Print Film can be handled under illumination provided by a standard safelight fixture fitted with a Kodak Safelight Filter, Wratten Series 8. With direct illumination, where the light from the bulb shines directly through the safelight, the latter should be located not less than 4 ft from the working surface and a 15-w bulb should be used in the safelight lamp. Where indirect illumination is employed, a 25-w bulb may be used in the safelight lamp. It is advisable to make safelight tests in each room where the film is handled to be certain that the operating conditions are within safe limits.

Greater efficiency may be obtained by the use of a sodium-vapor lamp, suitably filtered, to absorb all energy emitted by the lamp except that confined to the narrow spectral region which includes the yellow lines (at about 589 $m\mu$) of the sodium spectrum. A suitable combination of filters for use with a sodium-vapor lamp is the Kodak Wratten Filter No. 23A plus No. 57. A neutral tint absorption filter of sufficient density is also needed to reduce the intensity level to within safe limits. For this purpose, the Kodak Wratten Neutral Density Filter No. 96 can be used. The particular density should be chosen on the basis of tests made under the actual working conditions.

The storage of the exposed film at 70 F up to eight hours produces no serious changes in the latent image. However, printing and processing schedules should be arranged to allow processing of the film as soon as possible after exposure. It is also desirable to keep the interval between exposure and processing the same from day to day or from one process to another.

Table V. Processing Steps for Eastman Color Print Film, Type 5382 and 7382.

1. Prebath	10 sec to 1 min
2. Spray rinse	10–20 sec
3. Color development	12–15 min
4. Spray rinse	10–20 sec
5. First fixing bath	4 min
6. Wash	4 min
7. Bleach	8 min
8. Wash	2 min
9. Partial drying after squeegeeing	30 sec
10. Sound-track development	10–20 sec
11. Wash	2 min
12. Second fixing bath	4 min
13. Wash	8 min
14. Stabilizing bath	5–10 sec
15. Dry	15–20 min

Processing

The processing steps for Eastman Color Print Film with approximate times are

shown in Table V. The formulas for the prebath, first and second fixing baths and bleach solution are the same as those used for processing Type 5248 Film. A different color developer formula is used for Type 5382 Film. In addition, special solutions are needed for sound-track development and for the stabilizing treatment.

For a specific installation, the processing times may be slightly different from those shown in the table, depending on the amount of solution agitation, the film velocity, amount of solution carry-over, machine design, etc. The recommended processing temperature is 70 F. Temperature control equipment should allow for holding the developer solution within plus or minus three-tenths of a degree of the recommended temperature and for holding the other solutions within one or two degrees and the wash water within two or three degrees of this value.

The formula for the color developer is as follows:

Color Print Developer (Kodak SD-31)

	Avoirdupois	*U.S. Liquid*	*Metric*
Water, about 70–75 F (21–24 C)	96 gal	100 fl oz	800 ml
Kodak Anti-Calcium, sodium metaphosphate, sodium hexametaphosphate or Calgon (Calgon, Inc.)	2 lb	115 grains	2.0 grams
Kodak Sodium Sulfite, desiccated	4 lb	230 grains	4.0 grams
Kodak Color Developing Agent CD-2 (2-amino-5-diethylaminotoluene monohydrochloride)	3 lb	175 grains	3.0 grams
Kodak Sodium Carbonate, monohydrated	20 lb	2 oz 290 grains	20.0 grams
Kodak Potassium Bromide	2 lb	115 grains	2.0 grams
Water to make	120 gal	1 gal	1.0 liter

pH (70 F), 10.65 ± 0.05
Specific gravity (70 F), 1.023 ± 0.003

A word of caution is in order about handling the Color Developing Agent CD-2. This may cause dermatitis (inflammation of the skin) among individuals exposed to it, and in some instances serious complications can result. Only a strict adherence to rigid discipline at all points where there is contact with this chemical or the developer solution will hold to a minimum the number of cases of chemical dermatitis among laboratory personnel.

Processing of the sound track is carried out in a side tank after partial washing after the bleaching operation. After leaving the wash water, the film is thoroughly squeegeed to remove all surface moisture. Thorough drying is advantageous in obtaining uniform sound-track development. Sound-track development can be carried out by means of an applicator wheel which applies the developer solution only to the sound-track area. An applicator wheel which is satisfactory for this operation is illustrated in Figs. 5 and 6. The sound-track developer is of such viscosity that with proper adjustment of the distance between the wheel and the film, a bead can be maintained to give application over the required area. A dial indicator may be used to indicate the bead distance and an arrangement such as that shown in the illustrations should be provided to allow adjustment of the distance for proper application. The applicator wheel dips into a small tray containing the developer. The latter should be continuously

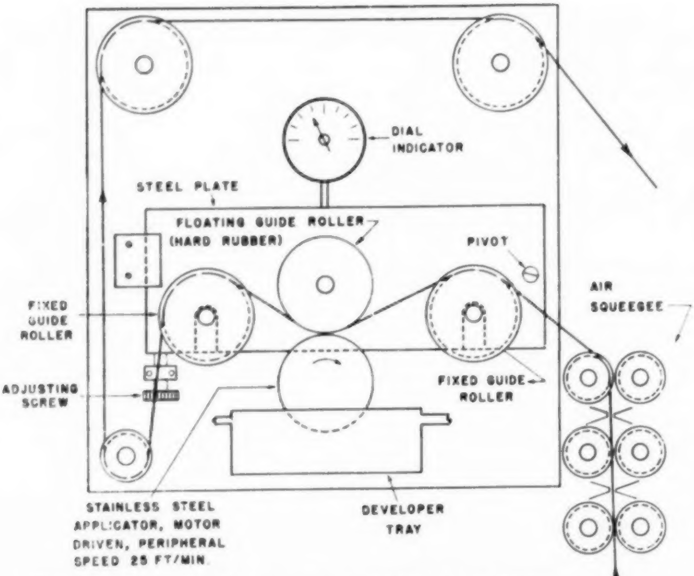


Fig. 5. Schematic diagram of sound-track applicator.

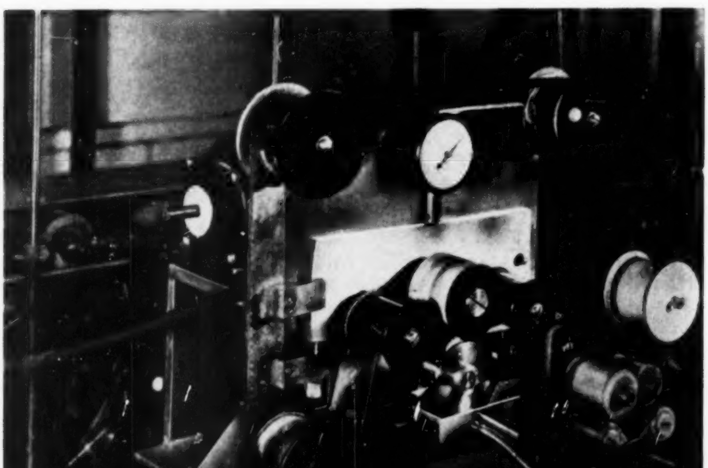


Fig. 6. Sound-track applicator.

replenished. The overflow must be connected to a separate drain rather than allowing it to enter the wash tank, since the contamination of the wash water by the sound-track developer may cause silver development in the picture area.

Sound-track development requires about 10 to 20 sec and a film path necessary to allow full reaction time must be provided before the film is returned to the wash water. Excess sound developer should be removed from the film before it is returned to the wash tank by means of a water squeegee so positioned as to direct a stream of water along the film surface away from the picture area toward the sound track. The rinse water is collected in a catch basin equipped with a separate drain.

The sound-track developer has the following composition:

Sound-Track Developer (Kodak SD-32)

	U.S. Liquid—Avoirdupois	*Metric*
Solution A		
Water	77 fl oz	600 ml
Kodak Sodium Sulfite, desiccated	$5\frac{1}{4}$ oz	40 grams
Kodak Elon Developing Agent*	$5\frac{1}{4}$ oz	40 grams
Kodak Sodium Hydroxide (caustic soda) while cooling, add with stirring	$10\frac{1}{2}$ oz	80 grams
Kodak Hydroquinone, dissolve completely	$5\frac{1}{4}$ oz	40 grams

* The Elon will not dissolve completely until the sodium hydroxide has been added.

Solution B		
Gum tragacanth (industrial grade)†	290 grains	5.0 grams
Place in a thoroughly dry, clean, one-liter beaker, then add:		
Alcohol (3A Specially Denatured)‡	$1\frac{1}{4}$ fl oz	10.0 ml

Swirl in the beaker until the mixture is distributed over the bottom and on the sides of the beaker to about one-third its height.

Add:		
Water, about 70 F (21 C)	38 fl oz	300 ml
Sodium hydrosulfite	8 oz	60 grams
Mix Solutions A and B and add:		
Ethylenediamine (60–70% by weight)	$2\frac{1}{2}$ fl oz	20 ml
Water to make	128 fl oz	1000 ml

(Note: This solution does not keep well and should be made fresh every 48 hr.)

† The purer grades of gum tragacanth are more difficult to get into solution and an industrial grade is therefore specified.

‡ Ethyl alcohol, specially denatured ,with technical grade wood alcohol. Minimum 190 proof. License must be obtained from District Supervisor of the Alcohol Tax Unit of the Bureau of Internal Revenue.

After the sound-track development, the film is returned to the wash tank to remove any remaining products, which, if carried over, would contaminate the second fixing bath. The second fixing bath and final wash treatments are the same as those described for the Color Negative Film.

The final washing is followed by a

formaldehyde stabilizing solution which improves the stability of the magenta image. This solution also includes a wetting agent to prevent formation of drying marks. The stabilizing bath has the following composition:

Stabilizing Bath for Color Motion Picture Film (Kodak S-1)

	U.S. Liquid—Avoirdupois		*Metric*
Kodak Formaldehyde, about 37% solution by weight	$4\frac{3}{4}$ gal to 6 gal	5 to $6\frac{1}{2}$ fl oz	40 to 50 ml
Kodak Photo-Flo Concentrate	1 gal 26 fl oz	$1\frac{1}{4}$ fl oz	10 ml
Water to make	120 gal	1 gal	1.0 liter

The stabilizing treatment should be between 5 and 10 sec. Times of treatment longer than 10 sec, or excessive formaldehyde concentration, cause yellow stain.

The stabilizing bath is replenished continuously, allowing the overflow to pass to the drain. Excess solution is removed from the film by means of an air squeegee. To prevent contamination of the workroom with formaldehyde vapors, a ventilating hood should be provided over the stabilizing solution tank.

Because of the differences in refractive indices of the wet gelatin and wet coupler solvent remaining in the film, the latter has an opalescent appearance before drying. Upon drying, the refractive indices of the gelatin and coupler solvent become equal and the opalescence disappears. Drying conditions normally employed for drying black-and-white films are satisfactory providing there is sufficient air circulation so that the emulsion temperature is not excessive. High drying temperatures may cause excessive curl.

A typical processed print is illustrated in Plate II.

Establishing a Standard Process

As in the case of processing of the Color Negative Film, a period of operation will be required before a standard process can be established. The same procedures which were discussed in relation to the color negative film also apply here.

Replenishment of the solutions is preferably carried out in a continuous manner. Replenishment formulas and rates should be determined for each installation on the basis of the chemical analysis data.

Process Control

The primary method used for process control is the same as that described for the color negative process, namely, control of the mechanical variables and chemical composition of the solutions. Practical operating limits are determined by what variations in photographic quality can be tolerated. Some suggested limits for each of the important constituents of the solutions are given in Table IV.

As a secondary or corroborative means of control, sensitometric methods are employed. Sensitometric control strips should be exposed in an intensity-scale instrument which provides a light-intensity level and exposure time comparable to that which the film receives in a motion-picture printer. With the exception of the Eastman Processing Control Sensitometer, the types of equipment discussed in the section on Type 5248 Film are satisfactory.

The strips can be exposed to give single-layer exposures which will result in cyan, magenta and yellow dye scales in the processed film. The densities of the dye deposits can then be measured to give integral densities[6] which will describe the behavior of the individual layers of the print film. This technique is preferable to making a gray-scale exposure and reading integral densities

therefrom, because it permits a more straightforward analysis of variations occurring in the film and/or process. With a tungsten light source operating at 3000 K, the following filter combinations may be used in the sensitometer, scene tester or printer for making the single-layer exposures:

Emulsion Layer to Be Exposed	*Kodak Wratten Filter*
Red-sensitive . . .	No. 29
Green-sensitive . .	No. 16 plus No. 61
Blue-sensitive . . .	No. 2B plus No. 49

The dye deposits can be measured on a suitable photoelectric color densitometer using red, green and blue light. In a densitometer equipped with a photocell having an S-4 type surface, such as is used in the Eastman Electronic Densitometer Type 31-A,[8] filter combinations having specifications similar to those given in Fig. 2 can be used satisfactorily.

Idealized curves for Eastman Color Print Film are shown in Fig. 7. The shouldering of the integral density curve for the yellow scale should not be interpreted to mean that the film lacks density to blue light in the high density regions. Both the magenta and cyan dyes have some density to blue light, hence when the three layer exposures are superimposed, the integral density to blue light in the higher density regions is adequate to give a neutral balance.

Projection of Prints

Release prints made on Eastman Color Print Film can be color-timed during printing to give proper color quality in the projected image for either tungsten or arc light projector illuminants. In most cases, prints will be balanced for use with the latter illuminant. In case it is desired to use such prints with a tungsten projector source, the light quality may be corrected approximately with a combination of a Kodak Wratten Filter No. 78B and a Kodak Color Compensating Filter CC-05G. A print which was originally timed for use with a tungsten projector source but which is to be used with an arc projector, may be corrected approximately with a combination of Kodak Wratten Filter No. 86A and a Kodak Color Compensating Filter CC-05M over the projector lens.

Care of Processed Prints

In order to obtain the greatest projection life for the color release prints,

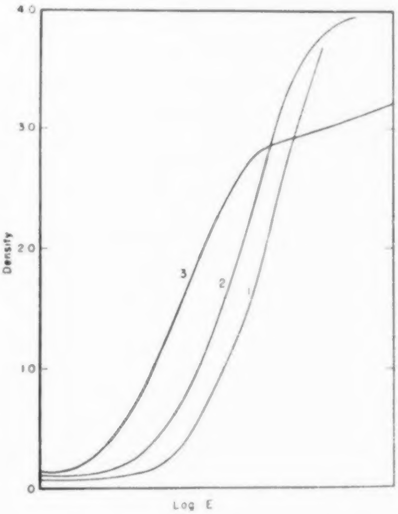


Fig. 7. ***D*-log *E* curves for Eastman Color Print Film, Type 5382.**

Exposure, intensity-scale sensitometer, 1/100 sec.

Illumination, tungsten, 3000 K, separate exposures through Kodak Wratten Filters (1) No. 29, (2) No. 16 plus No. 61 and (3) No. 2B plus No. 49.

Density, (1) red density of cyan scale, (2) green density of magenta scale and (3) blue density of yellow scale, all filters of Fig. 2.

Densitometer, Eastman Electronic Color Densitometer, Type 31A.

the same precautions concerning splices, lubrication, projector maintenance, etc., should be observed as those considered to be good practice in connection with black-and-white release prints.[9]

In the interest of obtaining the longest life during storage, the same conditions should be established as described for the color negative.

IV. Printing Eastman Color Negative Onto Eastman Color Print Film

It will be desired to print directly from color negatives made on Eastman Color Negative, onto Eastman Color Print Film in preparing work prints in color or small quantities of release prints from footage containing no special effects.

Printing Equipment

The ideal printing equipment for printing integral-tripack type color negatives onto similar-type release print materials provides facilities for automatic control of both the exposure and color balance for each scene.

For some purposes, however, such as in making color-balance tests and in preparation of dailies, printers of more limited versatility may be adequate. Such printers might provide only for adjustment of the exposure level for each scene at a fixed color balance and for manual adjustment of the latter. Various modifications of existing black-and-white printers have been made and used successfully in the industry for these purposes.

Modification of the color quality of the illumination in a printer can be accomplished in two general ways, by additive or subtractive methods.

In the additive method, red, green and blue light of appropriate spectral composition is obtained from either three separate filtered sources or from a single source in which the light is divided into three beams by use of beamsplitters or prisms and then filtered. The separate light beams are modulated and recombined at the printing aperture. Modulation of the intensities of each beam is effected by mattes, vanes, diaphragms or neutral density filters which are actuated automatically by means of information in the way of notches on the negative, magnetic track or other device. In this manner, both the color balance of the illumination and the overall intensity can be adjusted correctly for printing each scene.

An additive-type illumination system has been described by Streiffert,[10] in which the light from a single source is divided into three beams, each of which is filtered, modulated in intensity by rotatable vanes, then recombined at the printer aperture. A photoelectric monitoring system is used to adjust the intensity of the separate beams to provide the correct overall intensity and a punched tape serves to monitor the system for scene-to-scene color-balance changes. At a printer speed of 100 fpm, color-balance changes can be effected within about one-quarter of a frame. Some commercial laboratories have designed and built additive printers using other schemes.

The additive method of printing is the preferred method. The spectral passbands for the separate light beams can be selected by means of the proper filters so as to encompass any given group of wavelengths appropriate to the spectral transmittance characteristics of the negative dyes, and the spectral sensitivities of the separate layers of the print film. The use of narrow-wavelength bands in additive printing systems gives results which are superior in color saturation to those obtained using broader-wavelength bands or with subtractive systems. Printers employing the additive principle are also to be preferred because of their versatility.

In the subtractive method, a single light source is used and portions of the energy are subtracted in certain spectral regions by means of compensating filters, which are inserted in the beam. In some cases, neutral density filters are also used to keep the overall intensity constant for different filter combinations. Exposure timing is then accomplished by means ordinarily employed in black-and-white printers.

In subtractive type printing, the overlapping absorptions of the filters lead to certain difficulties. Ideally, such filters should have spectral absorptance curves with steep gradients, so that changes in the energy distribution of the printing illuminant can be effected over a specific bandwidth consistent with the negative dye image spectral transmittance characteristics and with the spectral sensitivity characteristics of the print film. Since this is not the case, combinations of such filters, especially when a large number is used, result in a loss in color contrast and saturation. Furthermore, it cannot be assumed that the removal of a given filter from a filter pack is equivalent to adding a complementary color filter of the same peak density. Examination of the spectral transmittance curves for two such packs will quickly show that they are not equivalent. Furthermore, if neutral density filters are used in conjunction with compensating filters to keep the overall intensity constant for various filter pack changes, the departure of neutral density filters from complete neutrality may introduce further errors. Such a system may become rather inefficient in the utilization of the available illumination. Finally, compensating filters cannot be expected to remain perfectly stable over long periods of time in high-intensity light beams, even when heat-absorbing glasses and forced ventilation are used.

A real challenge to printer designers and manufacturers exists to make equipment available to the industry which will be ideally suited for production color release printing.

Exposure of Color Print Film

Picture Exposure: Eastman Color Print Film requires considerably higher levels of illumination to obtain proper exposure than those ordinarily used in making black-and-white release prints. In a Bell & Howell Model D Printer modified for subtractive printing, with the necessary color-compensating filters in the beam but no neutral density filters, and equipped with a 300-w Bell & Howell Reflector Lamphouse, the proper exposure can be obtained through a color negative of average density at a printer speed of 40 fpm and a printer light setting of about 10. Under such conditions, the actual illuminance at the printer gate with no negative in position is of the order of 9000 lux. For higher production speeds, it would be necessary to use tungsten lamps of at least 1000-w rating.

In additive systems, the size of the lamps to be employed will depend on the efficiency of the optical system and the spectral bandwidth employed for each beam. For three light-source printers, lamps of 300- to 500-w rating should be adequate. For single light-source additive type printers, it is advisable to design the system to use a 1000-w lamp. This will usually permit printing to be done at reasonable production speeds even when the lamp is operated at voltages somewhat lower than the rated voltage.

Filters: In both subtractive and additive systems, it is desirable to insert a suitable heat-absorbing glass in the beam and to provide forced ventilation to keep the filters cool. A satisfactory heat-absorbing glass is the Pittsburgh Heat-Absorbing Filter No. 2043. In subtractive printing, the filter pack should contain, in addition to the compensating filters, a Kodak Wratten Filter No. 2B to absorb the ultraviolet portion of the energy emitted by the tungsten source.

Table VI. Filter Corrections With Subtractive Printing Systems.

Effect noted in reproduction	Correction needed in filter pack
Excessive yellow	Add yellow filter, (CC-05Y), etc.
Deficiency in yellow or excessive blue	Remove yellow filter, (CC-05Y), etc. or Add blue filter, (CC-05B), etc. or (CC-05M + CC-05C) etc.
Excessive magenta	Add magenta filter, CC-05M, etc.
Deficiency in magenta or excessive green	Remove magenta filter, (CC-05M, etc.) or Add green filter, (CC-05G etc.) or (CC-05C + CC-05Y) etc.
Excessive cyan	Add cyan filter, (CC-05C, etc.)
Deficiency in cyan or excessive red	Remove cyan filter, (CC-05C, etc.) or Add red filter, (CC-05R, etc.) or (CC-05Y + CC-05M) etc.

The Kodak Compensating Filters are supplied in yellow, magenta, cyan, red, green and blue in a series of six different densities for each color as follows:

CC-05Y, CC-10Y, CC-20Y, CC-30Y, CC-40Y, CC-50Y Yellow (blue-absorbing), with the same increments in the other colors.

The numbers of these filters, divided by 100, indicate the average density of the filter in the wavelength regions embraced by the absorption bands of the filter. They may be obtained in either gelatin sheets or in the cemented-glass type, but the former are more convenient for use in a printer. A qualitative description of the influence of these filters on the color balance of the final prints is given in Table VI.

In case it is desired to incorporate neutral density filters in the beam, in addition to the color-compensating filters, the Kodak Wratten Neutral Density Filter No. 96 is available in various densities, in gelatin sheet form or cemented-glass type.

For additive systems, each of the three light beams must be filtered appropriately to give red, green and blue light, respectively. It is possible to use various filters for this purpose, but better results are obtained if the filters are so chosen to give light confined to relatively narrow spectral regions with peak transmittances appropriate to the transmittance characteristics of the negative image dyes and to the peak sensitivities of the emulsion layers of the print film. For a three-light source type printer, a suitable combination of filters is as follows:

Light Beam	*Heat-Absorber*	*Wratten Filter No.*
Red	Pittsburgh Heat-Absorbing Filter No. 2043	70
Green	Same as for red beam	57 plus 15
Blue	Same as for red beam	47B plus 2B

In additive printers employing a single light source, the choice of filters will depend on the design of the beamsplitting system. Use of interference-type dichroic mirrors gives the most efficient use of the available light. Such mirrors can be made to give sharp cutoffs at specified wavelengths and high efficiency in regions of the spectrum in which they are intended to reflect. These mirrors can be combined with certain Kodak Wratten Filters to give the required spectral bands. The following specifications for bandwidth and wavelength of maximum transmittance for filter combinations are suggested:

Light Beam	Wavelength of Maximum Transmittance, mμ	Bandwidth, mμ
Red	690	675–700
Green	545	510–580
Blue	455	430–470

Color Balancing of Printers: In adjusting the color balance of a printer for use with a given emulsion number of print stock, the most practical procedure is to make a series of exposures at various light-intensity levels from a set of selected color negatives which are known to have received standard color negative processing. Such negatives should include several different types of subject matter and some, at least, should consist of close-ups of people. Such test negatives should preferably include in the original scene a gray scale and color patches. In practice, it is generally found that the gray scale is not reproduced as a gray scale in the print when the color balance of the printer has been adjusted to give the most pleasing picture quality. However, it is desirable to know just how such a scale is reproduced because this may be helpful when rebalancing a printer for a new emulsion number of print stock.

Picture judgments should be made, in the beginning at least, under the standard projection conditions which will be used for projection of the release prints. As experience is gained in making such judgments, it is possible to correlate them with judgments made with the aid of a suitable table projector.

When a new emulsion number of print stock is to be used, a new series of tests must be made to readjust the color balance of the printer for the new stock. If sensitometric comparison tests have previously been made on the two stocks, the results of such tests can be used as a rough guide in determining the changes which will be required for the new printer balance. Sensitometric comparison tests cannot be used as a precise guide in most cases because the conditions will often be governed by the particular portion of the characteristic curve of the print film which is utilized for printing each of the test scenes. Slight differences in toe shape or other characteristic may therefore influence picture quality more than is realized from an examination of the sensitometric curves.

Color-Timing: In printing color negatives onto Eastman Color Print Film, a difference in overall exposure amounting to about 0.04 log exposure unit (about one Bell & Howell Printer step) is apparent in the print. With respect to color balance, an even smaller change in the printing exposure of one emulsion layer relative to the other two is apparent as a color-balance change. The variations both in exposure and color balance which can be tolerated for a particular scene, however, will depend on the scene composition, the subject matter, the brightness range of the scene, and whether a deliberate departure from neutral balance must be aimed for in order to compensate for certain adaptation effects.

Color-timing demands considerable experience in printing a wide variety of scenes and careful observation of the results obtained in the final projected picture. It is helpful, in the beginning, to make a series of picture tests, on the equipment to be used for production printing, which will show the effects produced in the print by small changes in overall exposure and color balance. These test strips should be mounted and kept on hand for ready reference.

It is possible to estimate roughly what photographic effect will be obtained for a given color-balance change in the printer by observing a test print through previously calibrated viewing filters made up from selected combinations of color-compensating filters. A better system, however, is to employ some type of instrument, such as the Herrnfeld Scene Tester or Houston-Fearless Scene Tester,

which will allow a test print to be made in which successive frames of the same scene are printed at a slightly different color balance. The frame which appears to have the best color balance for that scene can then be selected.

Even though each scene is correctly color-timed, further modification in the color balance may be required when a given scene is assembled with other scenes to give the cut negative for release printing. Such changes are often necessary to overcome adaptation effects resulting from observation of the scene immediately preceding the scene in question when the print is projected. These changes can only be decided upon after looking at the first trial release print.

Printer Control: It is important to have some means for frequent checking of the printer with respect to intensity and color quality of the illumination at the printer aperture. A suitable photoelectric method has been described in a previous paper by Horton.[11]

Sound-Track Exposure: The sound track may be printed optically or by contact from black-and-white sound negatives made in the conventional manner. Either variable-density or variable-width sound tracks may be printed satisfactorily. Under optimum exposure conditions, the frequency response obtainable with Eastman Color Print Film, Type 5382, is better than that obtainable with the earlier Type 5381 Film but is not equivalent to that obtained from black-and-white prints on Eastman Fine Grain Release Positive Film, Type 5302.

The sound-track image is exposed in the top two layers of the print film. This is accomplished by the use of the filter combination: Kodak Wratten Filter No. 12 plus No. 2B plus Kodak Color Compensating Filter CC-50C.

The exposure level should be adjusted on the basis of listening tests or, if equipment is available, on the basis of intermodulation tests for variable-density tracks or cross-modulation tests for variable-width tracks. With such tests, it is possible to determine the print density for the unbiased, unmodulated track which will result in adequate cancellation and minimum distortion in the reproduced sound. The optimum print density for the Type 5382 Film is somewhat lower than that for the Type 5381 Film.

Since the sound track consists of both silver and dye images, the densities should be determined on a densitometer which has been modified to permit density readings to be made in the infrared, as described by Lovick.[12]

V. Eastman Panchromatic Separation Safety Film, Type 5216

General Description

As outlined in Fig. 1C, black-and-white separation positives are prepared for the purpose of introducing special effects for creating dramatic emphasis, enhancing the mood of the story, etc. In preparation of such separation positives, it is also possible to correct portions of the original negative footage for contrast, density or color balance in cases where unavoidable or accidental variations have occurred in either or both the exposure and processing of the original color negative film. Even when not used for the above purposes, separation positives should be made to serve as protection masters for the valuable original in the event of damage to the latter during handling or printing.

Characteristics

Eastman Panchromatic Separation Safety Film, Type 5216, is a 35mm black-and-white panchromatic material having very low graininess and high definition. The graininess is of the same

order as that obtained with Eastman Fine Grain Panchromatic Duplicating Film, Type 5203; but the contrast range available, when processed in most standard negative developers, is somewhat higher. The definition is superior to that obtained with Type 5203 Film. The panchromatic sensitivity of this film extends far enough into the longer wavelengths to permit use of a Kodak Wratten Filter No. 70 for preparation of the red separation positive. The film contains an absorbing dye in the emulsion, which is not fully removed during the processing. This dye imparts a greenish tint to the processed film.

The emulsion is coated on a clear safety base and the film is perforated with American Standard Negative perforations. Rolls are supplied in 1000-ft lengths with standard cores and winding.

The film may be handled under illumination provided by standard safelight fixtures, fitted with a Kodak Safelight Filter Wratten Series 8 or the Wratten 6B, ordinarily employed for use in handling x-ray materials.

Eastman Panchromatic Separation Safety Film may be stored under the conditions used for storage of Eastman Fine Grain Panchromatic Duplicating Negative Film, Type 5203. For periods of time up to one month, the storage temperature should not exceed 65 F. For storage periods up to six months, the temperature should not exceed 50 F.

Processing

This film may be processed in most developers ordinarily used for processing black-and-white negative materials. Since formulas for black-and-white negative processing vary widely from one laboratory to another, no specific times of development can be given. Where no particular negative formula is readily available, it is suggested that the Kodak Developer D-76 with additional potassium bromide (0.4 gram per liter) be used. Recommended processing temperature is 70 F. Fixing and washing operations may be the same as those used for regular black-and-white negative films. A typical set of processed separation positives is shown in Plate II.

In all cases, it is recommended that sensitometric test strips be prepared for the blue, green and red separation positives using in the sensitometer a tungsten light source and the filter packs normally used for making separation positives (given in a later section of this paper). A series of development times should then be given for each of the three separations, using the particular negative formula and equipment available and from these time-gamma curves may be derived in the usual way. A development time may then be chosen to give the desired gamma according to the requirements of

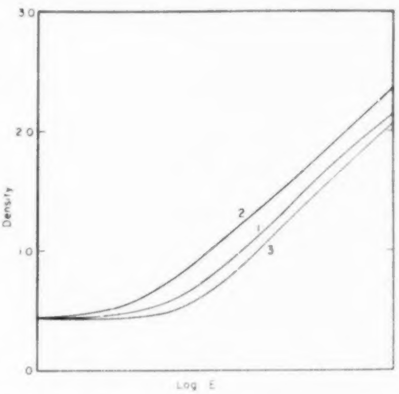


Fig. 8. *D*-log *E* curves for Eastman Panchromatic Separation Film, Type 5216.

Exposure, intensity-scale sensitometer, 1/25 sec.

Illumination, tungsten, 3000 K, plus Kodak Wratten Filters (1) No. 70 plus No. 96 (D = 0.40), (2) No. 16 plus No. 61 plus No. 96 (D = 0.10) and (3) No. 47B plus No. 2B.

Processing, Kodak Test Developer SD-28.

Density, diffuse density.

Densitometer, Eastman Electronic Color Densitometer, Type 31A.

the process. This is discussed in greater detail in a later section of the paper. Typical sensitometric curves for this film are shown in Fig. 8.

Densitometry

Densitometry of the red, green and blue separation positives may be carried out with any densitometer ordinarily employed for black-and-white films. If a visual-type instrument is used, a piece of fixed-out film or a green filter should be placed in the comparison beam of the instrument in order to facilitate making the readings.

Care of Processed Film

Proper storage of the processed separations is important in order to prevent differential shrinkage and to assure that perfect registration will be attained when these films are printed onto the subsequent color internegative or other materials. It is important that all three films be treated alike, as nearly as possible, after leaving the drying cabinet and up to the time they are printed. Each of the separations should be wound in the same direction on a 4-in. diameter core and placed in taped cans. It is also important that the temperature and humidity conditions of the various workrooms, wherever the separations are handled, be maintained within close limits, in order to minimize differences in shrinkage.

VI. Eastman Color Internegative Safety Film, Type 5245

General Description

Eastman Color Internegative Safety Film, Type 5245, is a new material designed to replace the former Type 5243 Film and is used as shown in Fig. 1C, for preparation of the color internegative from black-and-white separation positives. Such a color internegative will contain the special effects. The printing characteristics of the color internegative film are designed such that it can be intercut with original negatives made on Color Negative Film, Type 5248.

It may be feasible, of course, to prepare a color internegative of the entire footage which can be printed at a single exposure and color balance. This might be desirable, for example, for foreign release printing.

The film has the same structure as the earlier type Color Internegative Film, Type 5243.[2] A cross section is shown diagrammatically in Plate IV. The top layer of the film is a clear gelatin overcoating. The next layer consists of a blue-sensitive emulsion in which is dispersed a yellow-colored coupler. This coupler produces a magenta dye. The third layer is a clear gelatin layer. Beneath this is a blue- and green-sensitive emulsion in which is dispersed a reddish-orange colored coupler. This coupler produces a cyan dye. The fifth layer is a gelatin interlayer which separates the two bottom emulsion layers. The bottom emulsion layer is a blue- and red-sensitive emulsion which contains a colorless coupler. This coupler produces a yellow dye. On the side opposite the emulsion layers is a removable jet antihalation backing.

The dye image obtained in a given layer does not bear a complementary relationship to the spectral sensitivity of that emulsion layer as is found for Color Negative Film, Type 5248, and many other types of color films. The noncomplementary relationship between the dye image and spectral sensitivity of each layer is an advantageous scheme for avoiding loss of definition during the duplicating process.

Such an arrangement, however, causes no difficulty for the use intended, provided that the proper separation positives and filters are used to print each layer. Of course, if this film were used

in a camera for original photography, false color rendering of each area of the original scene would be obtained.

Characteristics

The emulsion and latent-image keeping properties of Eastman Color Internegative Film, Type 5245, and the storage requirements are similar to those previously described for Color Negative Film, Type 5248.

Eastman Color Internegative Film is furnished on a clear safety base with jet antihalation backing in 400- or 1000-ft lengths. It is provided with American Standard Negative type perforations but having shorter pitch dimensions.*

The speed of this material is very low and a high-intensity light source and efficient optical system are needed in the printer to obtain sufficient exposure. The contrast characteristics are appropriate for printing onto Eastman Color Print Film, Type 5382. They are somewhat higher than those of the former Color Internegative Film, Type 5243, hence lower contrast separation positives are required when printing onto this material than with the earlier type film. The graininess characteristics of this material are improved over the earlier type film.

Processing

Processing of Eastman Color Internegative Film, Type 5245, is carried out in the same solutions and in the same manner as used for processing Color Negative Film, Type 5248, with the exception that the color development time is 9 min. As with the Type 5248 Film, the actual processing times will vary somewhat with individual processing machines, depending upon the degree of agitation employed, replenishment rates, etc. A typical processed color internegative is shown in Plate II.

Process Control

The procedures previously described for establishing a standard process for the Type 5248 Film apply equally well here. The sensitometer or scene tester used for exposing the sensitometric strips on Color Internegative Film should provide an intensity level and exposure time comparable to that which the film receives in a step printer. The sensitometric strips must be exposed in such a way as to give a neutral scale. This is required in order to permit calculation of the gammas for the separation positives. With such a neutral scale, approximate integral printing densities to red, green and blue light can be obtained using the filters shown in Fig. 3, in the densitometer.

To make the neutral scale exposure on Color Internegative Film, it is necessary to make three separate, superimposed exposures with red, green and blue light, using the same filter combinations used when printing the separation positives onto the Color Internegative Film. The exposure times for the individual exposures which will result in a balanced exposure for the neutral scale must be determined by trial on the equipment being used.

Suitable filter combinations for the three exposures are as follows:

Exposure	*Kodak Wratten Filter*
Red	No. 29
Green	No. 16 plus No. 61
Blue	No. 34 plus No. 38A

When a sensitometer or scene tester is not available, it is possible to make these superimposed exposures in a printer. This requires a black-and-white negative containing a step tablet on each successive frame, as nearly identical as possible. Such a negative could be made in a title camera by photographing a precalibrated gray-

* Proposed American Standard, PH22.93, 35mm Motion Picture Short-Pitch Negative Film, *Jour. SMPTE, 59:* 527, Dec. 1952.

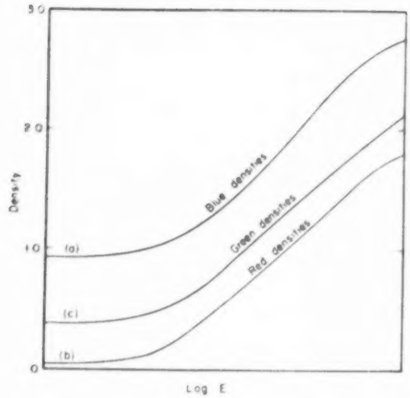


Fig. 9. *D*-log *E* curves for Eastman Color Internegative Film, Type 5245

Exposure, intensity-scale sensitometer, 1/25 sec.

Illumination, tungsten, 3000 K, with superimposed exposures through Kodak Wratten Filters (a) No. 29 plus No. 96 (D = 0.60), (b) No. 16 plus No. 61 and (c) No. 34 plus No. 38A plus No. 96 (D = 0.20).

Density, effective integral printing density to Eastman Color Print Film, as read with filters of Fig. 3.

Densitometer, Eastman Electronic Color Densitometer, Type 31A.

scale test object. Repeat exposures through this tablet, using the above filter combinations, could then be made onto the Color Internegative Film.

Idealized sensitometric curves for Eastman Color Internegative, Type 5245, are shown in Fig. 9.

Care of Processed Color Internegative

Since the color internegative will, in many cases, be intercut with original negative used for production release printing, it is important here, as in the case of the Type 5248 Film, to lacquer the film in order to protect the emulsion from permanent damage due to scratches.

Processed Color Internegative Film should also be stored under conditions which will prevent damage or deterioration. The information previously given with respect to storage of the processed Type 5248 Film, is equally applicable for this material.

VII. Making Separation Positives and Color Internegatives

General Procedure

The general procedure for making separation positives and color internegatives from original color negatives is illustrated diagrammatically in Plate V. The first step involves the preparation of the separation positives by means of exposures through appropriate red, green and blue filter combinations. The second step calls for printing these separations onto the proper layers of Color Internegative Film, using a different set of filter combinations. The resulting color internegative is then printed onto Color Print Film in the same manner as is done when printing from the original color negative.

Since the emulsion layers of Color Internegative Film have effective sensitivities which do not bear a complementary relationship to the color of the dye images produced in them, the actual color of the filter packs used in exposing the three layers may be misleading and some confusion may occur. To avoid this situation, it is helpful to refer to the blue separation positive as the "yellow printer," as indicated in Plate V, because it controls the amount of yellow dye image produced in the internegative. Similarly, the green- and red-separation positives are referred to as the "magenta printer" and "cyan printer," respectively. It is also helpful to refer to the

filter combinations used for printing the separations onto the internegative film as the "yellow printer pack," the "magenta printer pack" and the "cyan printer pack," rather than by their actual color.

Equipment

The general requirements regarding equipment, the techniques to be employed and the precautions to be observed in order to obtain accurate registration, are much the same as those used in process work or with other color materials. When effects are to be included in the separation positives, it is necessary to employ an optical-type registering printer. If no effects are to be included, then a contact step printer of the registering type may be used.

In order to obtain exact registration in both making and printing the separation positives, it is essential that for both stages of operation the full-fitting registration pin of the printer fall in the same perforation relative to the frame being printed. This may be accomplished by having separate printer gates for each of the printing steps, with the full-fitting pin in the proper position, or by having two illumination systems in the printer.

In a contact printer, duplicate optical systems, each consisting of a light source, filterholder and shutter, allow printing to be done from either side of the gate. The separation positives can be made with the original color negative to the left of the separation film raw stock and the positives can be printed onto the internegative raw stock with the latter in the lefthand position. In this way, all printing can be done emulsion to emulsion and the registration pins can be positioned in the same perforations relative to the frame during both stages of handling the separations.

Since the speed of the separation and internegative films is very low, the printer used in both stages must utilize a high-intensity light source and an optical system of high efficiency.

Making the Separation Positives

Filters: For making separation positives from originals made on Eastman Color Negative Film, Type 5248, the following filter combinations are used:

Separation	*Kodak Wratten Filter*
Blue Separation or *Yellow Printer* . .	No. 47B plus No. 2B
Green Separation or *Magenta Printer* .	No. 16 plus No. 61
Red Separation or *Cyan Printer* . . .	No. 70

Exposure: Because of slight differences in curve shape, improper reproduction of certain colors in the highlight regions of the scene may result if the highlight areas are exposed on the extreme toe portion of the curve. On the other hand, if exposure is too great, problems may be encountered when printing the separation positives onto the internegative film because of insufficient light in the printer.

Making the Color Internegative

Filters: For exposing the Color Internegative Film from the separation positives, the following filter combinations are suitable:

Filter Pack	*Kodak Wratten Filter*
Yellow Printer Pack	No. 29
Magenta Printer Pack	No. 34 plus No. 38A
Cyan Printer Pack .	No. 16 plus No. 61

Exposure: The exposure should be adjusted so that the overall density of the color internegative is slightly higher than a normally exposed original color negative. In no case should the color internegative be as light as an underexposed original negative. It is important that the picture be placed high enough on the characteristic curve of the internegative to avoid excessive distortion in shadow tone reproduction.

Calculation of Required Separation Positive Gammas: The overall gamma of the

duplicating step must be unity if it is desired that the internegative have the same contrast characteristics with respect to the print film as those of the original negative. This will be the case, in general, although there will be some instances where it will be desired to increase or decrease the contrast of the internegative relative to that of the original. The contrast relationships in the duplicating system may be stated as follows:

$$\gamma_{(N \longrightarrow 5216)} \times \gamma_{SP} \times \gamma_{(IN \longrightarrow 5382)} = \text{Print-through } \gamma_{(IN \longrightarrow 5382)} \quad (1)$$

where

$\gamma_{(N \longrightarrow 5216)}$ = Process gamma of original color negative with respect to Separation Positive Film, Type 5216.

γ_{SP} = Process gamma of separation positive.

$\gamma_{(IN \longrightarrow 5382)}$ = Process gamma of internegative with respect to Color Print Film, Type 5382.

Print-through $\gamma_{(IN \longrightarrow 5382)}$ = Print-through gamma of internegative with respect to Color Print Film, Type 5382.

If the process gamma of the original color negative is determined with a densitometer equipped with a set of filters (such as those shown in Fig. 3) which give approximate printing densities with respect to Color Print Film, Type 5382, the correct value for $\gamma_{(N \longrightarrow 5216)}$ can be calculated by using a correction factor. A different correction factor will be required for each of the filter combinations, thus:

$$P_r \times \gamma_{(N \longrightarrow 5382)} = \gamma_{(N \longrightarrow 5216)} \quad \text{(for the red combination)} \quad (2)$$

$$P_g \times \gamma_{(N \longrightarrow 5382)} = \gamma_{(N \longrightarrow 5216)} \quad \text{(for the green combination)} \quad (3)$$

$$P_b \times \gamma_{(N \longrightarrow 5382)} = \gamma_{(N \longrightarrow 5216)} \quad \text{(for the blue combination),} \quad (4)$$

where P_r, P_g and P_b are the constant correction factors which must be determined for the particular filters and densitometer used.

For the most general case, where the printing contrast of the internegative is to be equal to that of the original negative, we have:

$$\gamma_{(N \longrightarrow 5382)} = \text{Print-through } \gamma_{(N \longrightarrow 5382)} \quad (5)$$

Equation (1) then reduces to

$$P \times \gamma_{SP} \times \gamma_{(IN \longrightarrow 5382)} = 1 \quad (6)$$

Hence,

$$\gamma_{SP} = \frac{1}{P \times \gamma_{(IN \longrightarrow 5382)}} \quad (7)$$

Using the correction factors P_r, P_g and P_b and the measured process gammas from an internegative control strip, it is then possible to calculate the required gammas for the separation positives from Eq. (7).

In order to make use of Eq. (7), the internegative film exposure time for the control strip must not differ from that used for the final internegative and the density regions of the internegative characteristic curves chosen for measurement must be the *exact* regions upon which the picture will be printed. In addition, these regions (of red, green and blue curves) must be superimposed on the internegative control strip curve in order to avoid errors resulting from relative exposure displacement.

Acknowledgment

The authors wish to express their appreciation to all those people in the Manufacturing and Testing Divisions, the Color Technology Division, the Research Laboratories and the Motion Picture Film Department of the Eastman Kodak Company who have been responsible for the development work on these new films, and who have contributed so generously the information contained in this paper. On behalf of these people, the authors also wish to extend their thanks to those in the industry who, with their helpful suggestions and cooperation in making numerous practical tests, have helped to make this program a success.

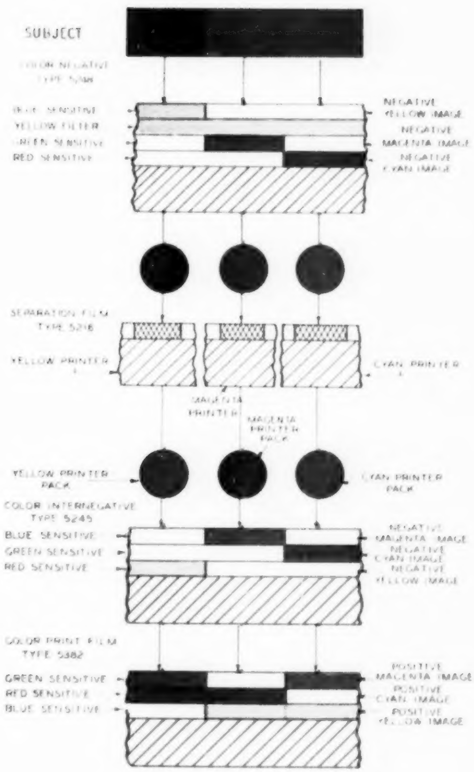


Plate V. Schematic Printing System

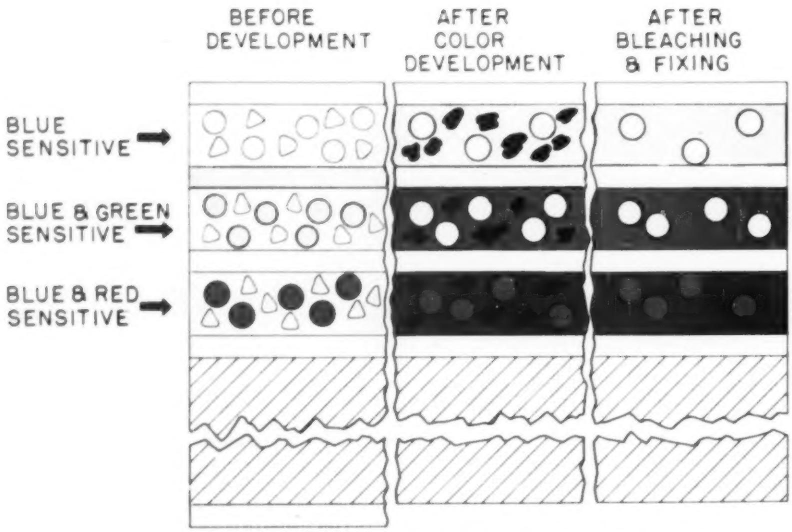


Plate I. Structure of Eastman Color Negative Film, Type 5248

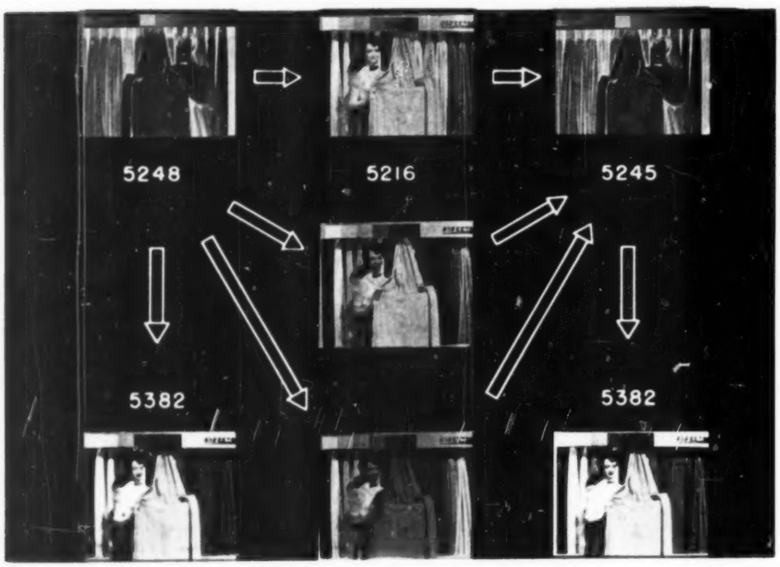


Plate II. Examples of Processed Films

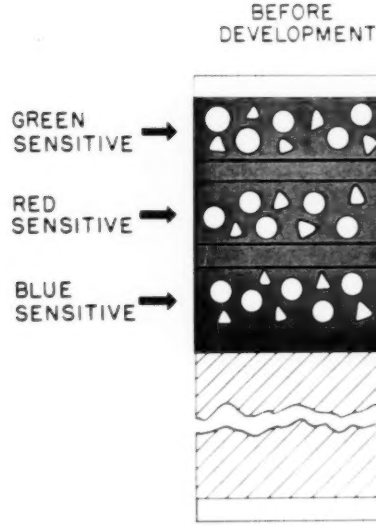


Plate III. Structure of East

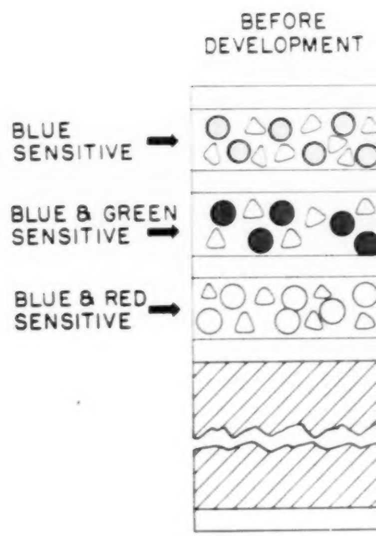
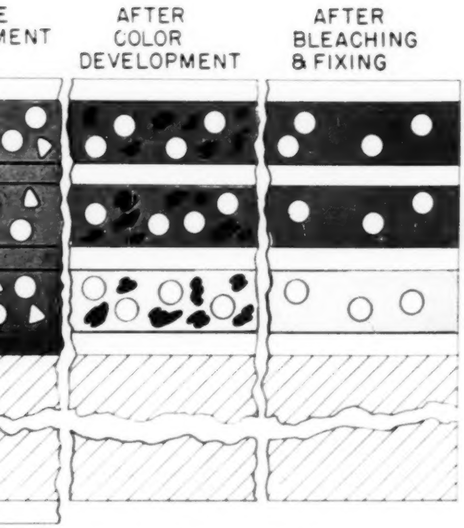
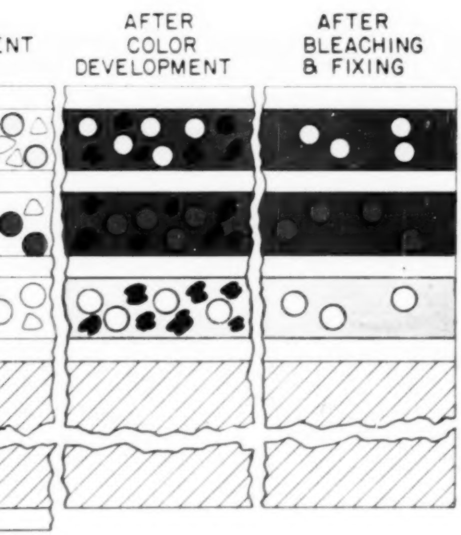


Plate IV. Structure of Eastman



Eastman Color Print Film, Type 5382



tman Color Internegative Film, Type 5245

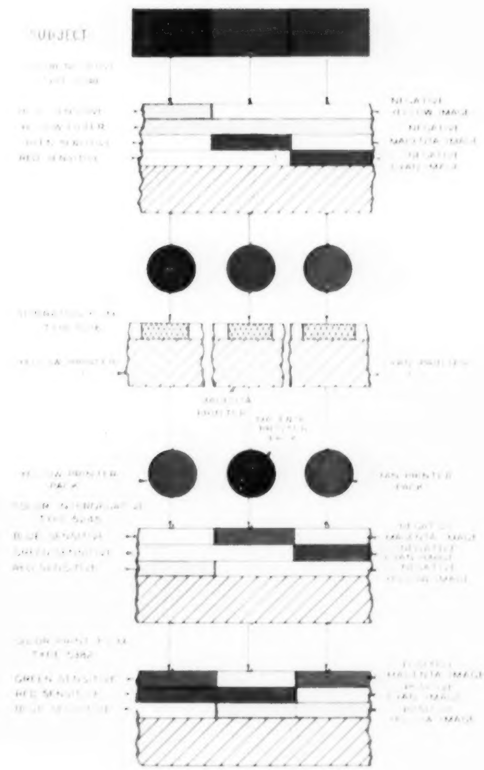


Plate V. Schematic Printing System

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Objective Evaluation of Projection Screens

By ELLIS W. D'ARCY and GERHARD LESSMAN

This paper describes a method for measuring rear-projection screen brightness compared to the reflectivity of a standard magnesium block.

THE INCREASING IMPORTANCE of wide-screen processes, three-dimensional projection, rear-projected educational films, process projection screens and large-screen television has put new emphasis on the projection screen as an optical element of the projection system and as the ultimate link between the audience and the film. The screen is, subjectively at least, the whole picture; and its apparent brightness, color and detail are unconsciously identified by the audience with the performonce of the entire projection system.

Although we know the approximate contribution of each individual element of the projection system to the end result, this common subjective estimate contains a germ of truth. There is in fact much more to be done at the screen by way of improving the brightness of the picture seen by the audience than at any other point in the optical system. For instance, although the limitations of projection equipment and presently available light sources make the attainment of even a small increase in screen illumination a commendable and difficult accomplishment, the effective screen brightness presented to the audience may vary 200%, according to the screen used.

Presented on April 22, 1952, at the Society's Convention at Chicago by Ellis W. D'Arcy and Gerhard Lessman, De Vry Corp., 1111 W. Armitage Ave., Chicago 14, Ill. (This paper was first received April 25, 1952, and in revised form September 18, 1953.)

Although many accurate measurements of screen characteristics are reported in the literature, their practical application has been limited, and the tendency has been to evaluate screens subjectively by simple visual comparison. This has been particularly true of rear-projection screens, because the lack of generally available instrumentation and of commonly accepted criteria and terminology has made objective evaluation difficult. Another reason for the absence of objective standards for rear-projection screens appears to be the greater intricacy of rear-projection illumination problems as compared to those involved in simple front projection. Front-projection screens act as simple diffusers which operate upon both the projected light and the ambient illumi-

nation according to the same set of reflection characteristics. Rear-projection or transmissive screens have separate and independent diffusion characteristics for the projected (transmitted) light and the ambient (reflected) light respectively. Their normal use under conditions of high ambient illumination emphasizes the importance of a knowledge of their reflective behavior for attaining good image contrast.

Three objective factors completely predetermine the behavior of rear-projection screens, and of front-projection screens as a special case thereof:

(a) photometric, including transmission and reflection at various projection and viewing angles, and color to the extent to which it affects the transmission and reflection;

(b) color, measured objectively, that is quantitatively by spectrophotometric methods, but for the purpose of establishing its subjective effect as mere color or departure from whiteness;

(c) resolution, measured as the size of the smallest detail resolvable upon the fine structure of the diffusing elements of the screen.

The subject of screen color appears to be adequately covered in an American War Standard[1] which prescribes spectrophotometric characteristics for diffuse-reflecting screens limiting the amount of permissible off-whiteness or tint. The authors consider this standard as acceptable and adaptable as well to rear-projection screens. Insofar as the screen color conforms to this standard, its effect is too slight to affect the photometric factors established by measurement with visually corrected photocells.

Screen resolution may be considered as the result of a complex of factors such as the graininess, line or facet structure of the screen, the depth of the diffusing elements, and the amount of transillumination from the highlights into adjacent shadow areas. An objective evaluation of screen resolution in terms of minimum detail size resolvable has become significant because a concept of small-screen, narrow-angle viewing for educational projection, stimulated by the success of television, has created some interest in small rear-projection screens of high resolution and brightness. Because of the large amount of experimental work to be reported, the authors plan to present their work on screen resolution in a subsequent paper.

What we have termed the photometric factors in objective screen evaluation derive from the simply understood characteristics of reflectance and transmittance of the screen when illuminated at various projection angles and as viewed from different viewing angles. Goniophotometric reflectance and transmittance, especially at singular points due to the influence of specular (glossy, nondiffuse) reflection or normal (nondiffuse) transmission, although readily comprehended as such, cannot be directly obtained experimentally nor evaluated visually. Photoelectric cells measure light intensity directly. The eye and visual photometers evaluate brightness by comparison, brightness being indeed the only objective comparative factor meaningful to the eye. Inasmuch as intensity is directly related to brightness as a function of the cosine of the angle of view, it is believed that a comparison of the brightness of a screen under any assumed condition of observation with the brightness of a standard material of universal acceptance would be objectively valid because of the relative ease and accuracy with which the corresponding intensity and angle measurements can be accomplished both upon the screen and the standard, and because of the instinctive subjective appeal of brightness as a direct visually significant quantity.

Freshly scraped chemically pure magnesium carbonate blocks were chosen as a standard conforming most closely to the well-known Lambert cosine law theoretical diffuse reflector. This stand-

ard is readily available to all, and departs so little from the theoretical cosine law diffuser that recomputation from the standard to a theoretical basis did not appear to be justified by the application intended. Our results are reported as "brightness ratios" to the brightness of magnesium carbonate under like conditions of illumination at various projection and viewing angles taken as unity. This approach is in accordance with the methods of an American War Standard[2] on reflective diffusing screen brightness characteristics whose terminology and methods appear to be appropriate and practical. Because of the rather large range of the brightness ratio ordinate, and because of the logarithmic visual response of the eye, a logarithmic brightness ratio plot was selected. A polar plot of the viewing angle was decided upon, because the angular distribution of light is more readily apparent from simple inspection of such a plot. The term "effective brightness gain" in use by some investigators[3] is merely a special case of a brightness ratio taken at the point of maximum brightness and as such has only limited usefulness, as will become apparent subsequently.

Analogous reasoning justifies this basis for transmission measurements. In this case, a hypothetical screen which diffuses all the incident light in a cosine distribution would yield the same intensity measurements and would have the same brightness at equal illumination as the standard. Similarly, the high intensity recorded when measuring a glossy or specularly reflecting material would be equivalent to the high intensity which would be recorded if a very transparent screen or no screen at all were set up in the transmission measurement position.

The instrument used for our measurements (Fig. 1) will be seen to be an elaboration of the goniophotometer built in 1920 by Loyd A. Jones,[4,5] of Eastman Kodak Co., in which the visual photometer head has been replaced by an accurate photoelectric photometer head and certain improvements in design have been effected. It will also be recognized as a refinement of the apparatus of Berger.[3] The instrument comprises a wooden base on which is mounted a lamphouse and two coaxial turntables. The upper turntable supports a rack which holds either the screen or a standardizing block of magnesium carbonate. An extension of the lower turntable supports a pedestal-mounted photometer head, connected by flexible leads to a bias network and a Ballantine vacuum-tube voltmeter. The several turntables are provided with indexing pins and holes for accurately indexing either the screen or the photometer head at 15° intervals.

A diagrammatic view of the instrument (Fig. 2) illustrates its function in reflectance measurement. The photometer head consists of an electrically and optically shielded housing for an objective lens and a lead sulfide photoelectric cell. The objective lens focuses a small image of a spot of light on the screen at the entrance face of a light pipe prism, a standard component of the De Vry sound-optical system, which scrambles or integrates the light and transmits it to the sensitive area of the lead sulfide cell with less loss than would result were an integrating sphere used.

The lamphouse encloses a 6-v, 18-amp vertical ribbon filament lamp, whose filament is directly imaged upon the screen. The light transmitted to the screen is freed from infrared radiation by a phosphate glass heat filter and is substantially white at a color temperature of approximately 2848 K. In order to provide a modulated input for the vacuum-tube voltmeter amplifier, light from the lamp is interrupted at a rate of 600 cycles/sec by a motor-driven light chopper disc. The brightness of the lamp is of course accurately

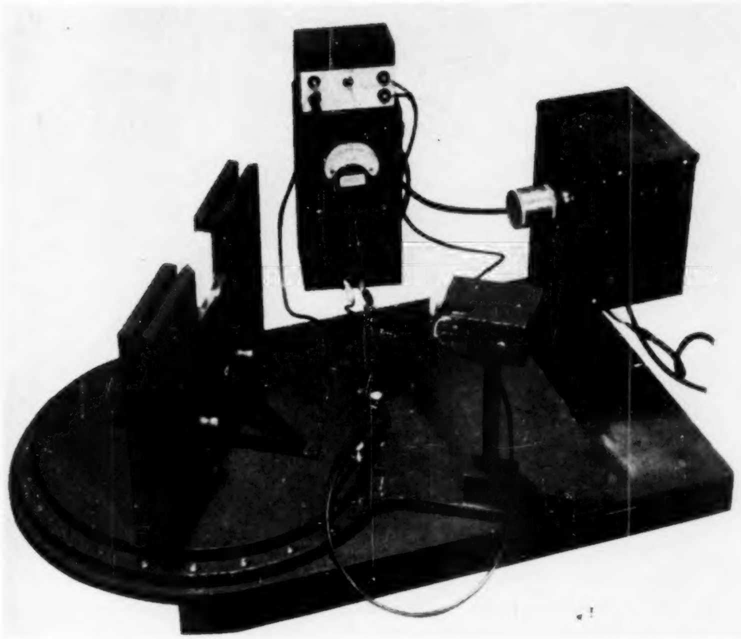


Fig. 1. Goniophotometer, with magnesium carbonate block in position for standardizing.

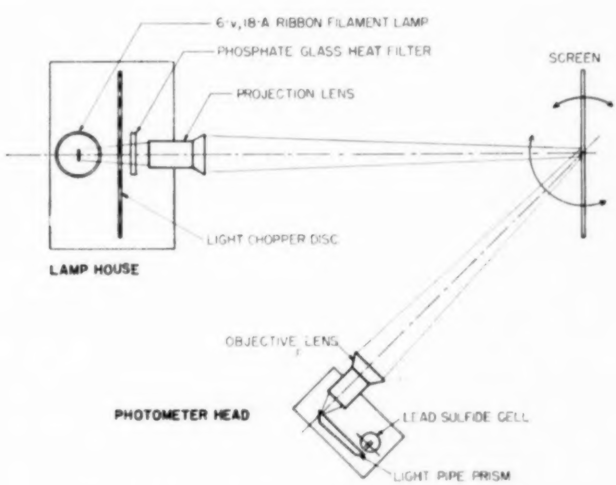


Fig. 2. Schematic diagram of goniophotometer.

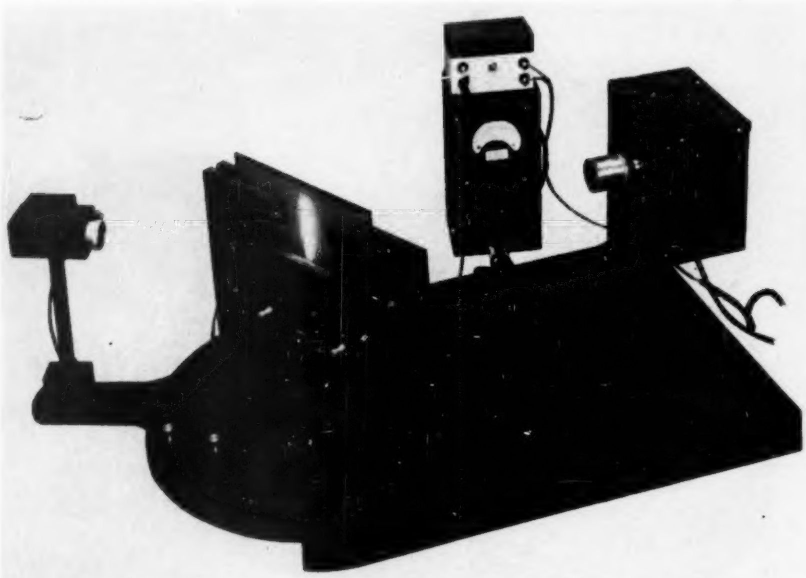


Fig. 3. Goniophotometer arranged for transmission measurements.

maintained through careful control of the supply voltage.

The physical dimensions of the apparatus are such that the half-widths of the light beams projected or picked up by the photocell are less than 1.5°.[2]

For transmission measurements (Fig. 3) the photometer head is positioned to pick up light from behind the screen. Angular adjustment of the screen and photometer head can be made with equal facility as in taking reflection measurements.

The probable absolute accuracy of this instrument as between separate sets of readings is believed to be well within 5%. The accuracy within any one set of readings (one goniophotometric curve) is believed to be about 2%.

Inasmuch as the instrument reads intensity directly and the intensity distribution of the magnesium carbonate is known to follow the Lambert law quite closely, a series of measurements was made and plotted against a theoretical cosine law curve (Fig. 4). The close correspondence is obvious and attests to the accuracy of our measurements. In measuring screen brightness the simple ratio of the screen intensity distribution to that of the magnesium carbonate standard was plotted as the brightness ratio, thus disregarding for practical purposes the few per cent difference between the standard and theoretical cosine law diffuser. As a test example, a good commercial matte white screen was measured and plotted (Fig. 5) in terms of the ratio of its brightness to that of magnesium carbonate under equal conditions of illumination. It will be noted that the brightness, although lower than that of magnesium carbonate, has the same semicircular distribution pattern, indicating that it is a Lambert law diffuser and that like all true Lambert law diffusing surfaces its brightness distribution is practically

Fig. 4. Goniophotometric curve of magnesium carbonate standard versus theoretical cosine law curve.

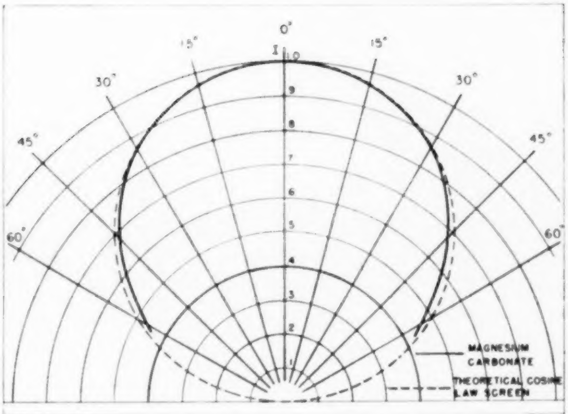


Fig. 5. Commercial matte white screen.

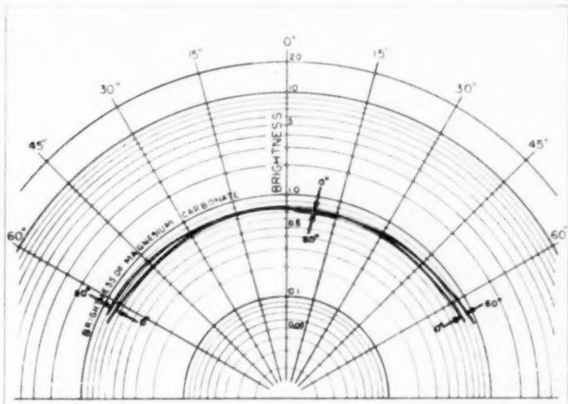
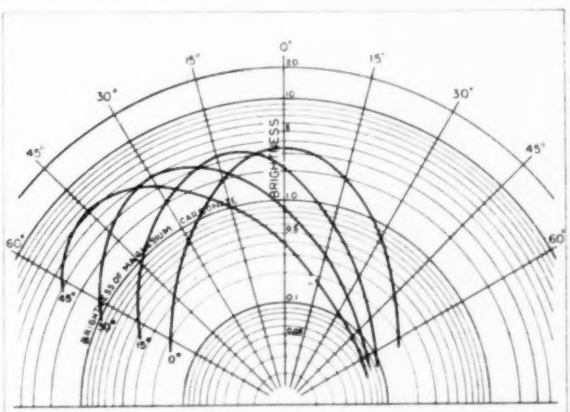


Fig. 6. Aluminized stereo projection screen.



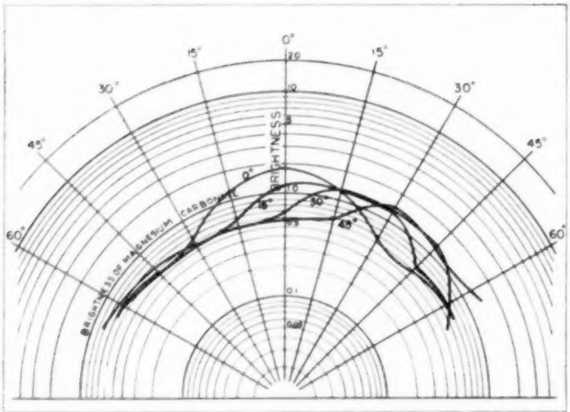


Fig. 7. Typical beaded screen.

unaffected by the angle of incidence of the projected light. This is apparent from the almost congruent 60° projection angle curve. As a further example of the type of results obtainable with our instrument and method of plotting, we present the brightness ratio curves of a rather specular type of screen (Fig. 6), a typical commercial aluminized screen used for stereo projection. The gain in center brightness of this screen, over four times that of magnesium carbonate, is quickly lost at even relatively small viewing angles, so that the so-called "brightness gain" at the normal viewing angle is very deceptive as to the screen's true performance under all conditions except specular viewing.

The next screen measured was a typical commercial beaded screen (Fig. 7). The interesting features of the curves for this screen are the basically cosine law distribution pattern of the screen except at the peaks, and the fact that the peak brightness occurs near but not exactly at the angle of incidence instead of at the opposite angle, a characteristic common to beaded reflective type screens.

The data on these three reflecting-type screens have been presented chiefly to illustrate the method of measurement and plotting, similar data for reflective-type screens having appeared in the literature[4–8] over an extended period. These data have been qualitatively properly interpreted in the past, particularly with reference to the selection of screens whose distribution curves complement the geometry of the theater[7] within which they are intended to be used. To our knowledge, however, there has been no attempt to correlate screen brightness characteristics with ambient light conditions in order to evaluate the available contrast or highlight to shadow brightness ratio. We shall elaborate upon this topic later, but at this point it must suffice to state that as between two front-projection screens, each having similar distribution curves, the maximum available contrast will be the same for both screens for equal conditions of projected and ambient illumination. The best front-projection screen, other factors being equal is simply the brighter one. This is definitely not true of rear-projection screens, as we shall show.

As an example of a typical rear-projection screen we shall now present the transmissive and reflective brightness ratio curves for a well-known commercial plastic rear-projection process screen (Fig. 8). Inspection of these curves

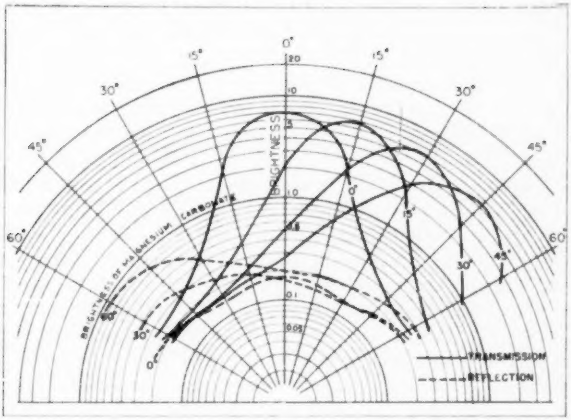


Fig. 8. Plastic rear-projection screen.

reveals that the transmissive brightness curves are similar in shape at different projection angles although their peaks are displaced at viewing angles in line with the corresponding angle of projection. The reflected brightness curves are a different family of similar curves and their specular peaks are of course at the angle opposite to the angle of projection. It is apparent that the brightness of the screen due to projected or ambient light of any specified intensity or direction can be read from these curves for any desired viewing angle, and that the brightness ratio or contrast range of highlight and shadow areas can thus be computed and plotted for any specified set of conditions. A natural desire to utilize the information exemplified by the above curves for evaluating a figure of merit should be restrained until the significance of these factors to the actual performance of the screen is clear. It is of course tacitly assumed that the resolution and color as well as the mechanical properties of the screen are satisfactory. In other words, one must have a screen before valid photometric measurements can be made on it. We shall, however, show a few brightness ratio curves for screens which do not have entirely satisfactory resolution in order to illustrate the photometric characteristics of the special materials of which they happen to be made.

Unlike simple reflective diffusing screens, transmissive diffusing screens may have characteristic reflection curves differing widely in shape and size from the transmission curves, so that a relatively inefficient transmissive screen of the "black" type, having a low transmissive brightness ratio, may yield an available picture contrast range far higher than a screen of greater light efficiency but proportionately higher reflecting power. It is necessary, however, that the transmissive brightness ratio meet certain minimum requirements, otherwise the picture will appear dim to the ambient illumination adapted eyes of the audience. This topic is no doubt being extensively investigated by the Society's Screen Brightness Committee, whose symposium on Screen Viewing Factors[9] ably developed certain aspects which are not within the scope this paper. The need for preserving a minimum level of screen brightness in the presence of unavoidable ambient or surround illumination diminishes the possibility of obtaining high contrast in the presence of high ambient illumination sometimes thought to reside in extra-dense black transmissive screens. Such dense screens simply do not give a

bright enough image at the illuminations possible with available projectors and light sources. Before going deeper into these considerations we wish to illustrate the brightness characteristics of some different types of rear-projection screens.

Figure 9 illustrates the brightness characteristics of a black plastic rear-projection screen similar to the process screen (Fig. 8) just shown except for its blackness. Comparison of the two sets of curves reveals that the black screen has a broader brightness distribution out to 15° or 20° and therefore less of a hot spot, and that the ratio of the transmitted brightness to that of the reflected brightness is larger; that is, there is greater contrast. The facility with which such comparisons can be made is one of the advantages of the logarithmic plot. A simple measurement of the ordinate difference between the transmission and reflection curves or between any other two points of interest represents a direct ratio, which can be read off against the ordinate scale.

Figure 10 illustrates the photometric properties of a rear-projection screen which consists essentially of a black beaded coating on glass. The transmission of this screen is much less than that of the black screen just shown but is characterized by a flatter angular distribution which results in less of a hot spot. This advantage is offset by the comparatively high reflectivity of the screen, which is not therefore capable of yielding as high a contrast range as the previous screen. This screen possesses a slight gloss which becomes rather specular at steep projection angles as shown by the 60° incidence reflection curve. The resolution of this screen is fair, corresponding to a beaded reflective screen.

Figure 11 illustrates the properties of an experimental rear-projection screen sample made by the manufacturers of the screen just shown. This is a very dark black beaded coating on plastic. Although the central brightness along the transmitted ray is almost the same as that of the previous screen, the angular fall-off is very rapid, which accounts for the low overall light efficiency of this screen. This screen can hardly be illuminated sufficiently to establish a bright enough picture to compete with reasonable ambient illumination. The screen suffers from a very high gloss which is evinced by the very steep reflection curves, which indicate a reflected brightness ratio at specular points greater than the brightness due to direct transmission. This means that the gloss from ambient illumination will, at some viewing angles, completely wash out the picture contrast.

The next two figures illustrate two rear-projection screens of still another manufacturer. Figure 12 represents an emulsion on white opal glass type of screen. Figure 13 represents the characteristics of an emulsion on black opal glass type of screen. The characteristic curves of these two screens are very similar in shape and distribution except that the brightness ordinates of the black screen are only about half the value of those of the white screen, with the white screen having on the whole an apparent contrast range, or ratio between transmissive and reflective brightness, greater than the black screen. Nevertheless even casual inspection establishes the obvious fact that the black screen has the higher contrast and is, for most applications, the better screen. This means that under some conditions the photometric characteristics taken by themselves are insufficient although valid objective criteria of screen performance. In this particular case, the white screen (Fig. 12) is afflicted with so much halation resulting from sideward diffusion or transillumination of light from the highlight into the shadow areas, that the contrast range of which the screen might be capable on the basis of the photometric curves cannot be realized ex-

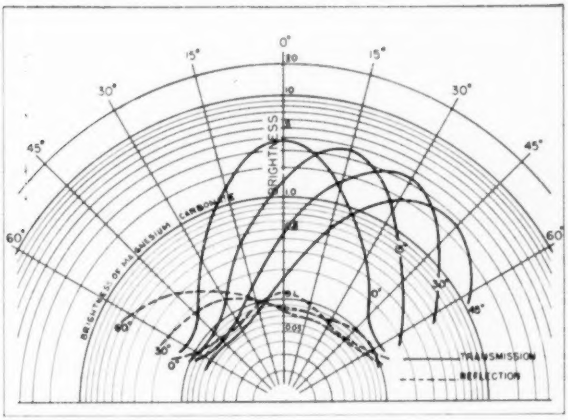


Fig. 9. Plastic black rear-projection screen.

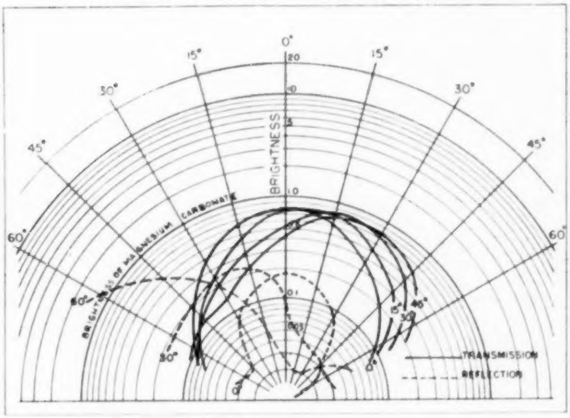


Fig. 10. Black beaded coating on glass.

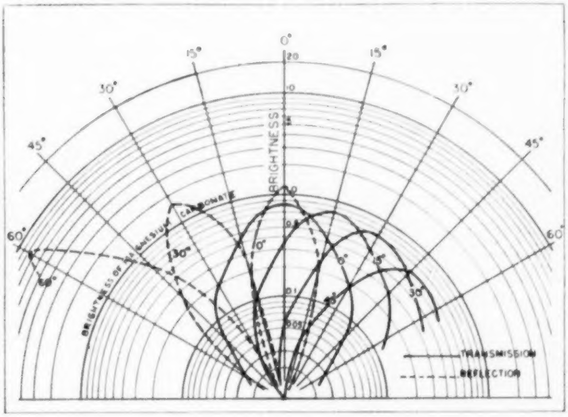


Fig. 11. Dark black beaded coating on plastic.

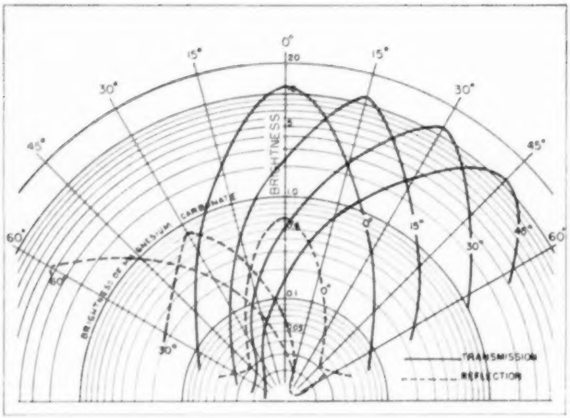


Fig. 12. Emulsion on opal glass.

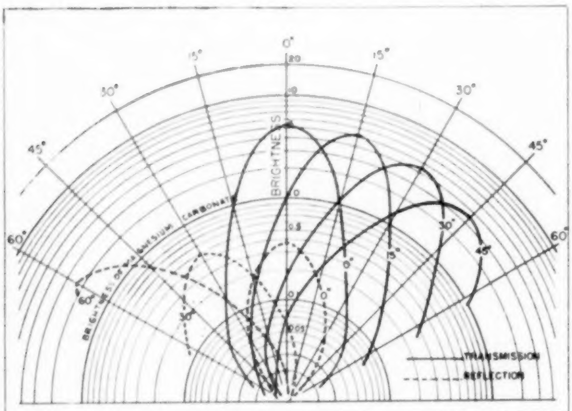


Fig. 13. Emulsion on black glass.

cept by the artificial expedient of placing two noncontiguous samples of the screen side by side under the same ambient illumination, one being highlighted by projection, the other representing shadow brightness. A continuous sample of the screen appears to be completely transilluminated over a large area around each highlight. The rule apparently applicable here is that the low-contrast factors (the halation) predominate over the high-contrast factor (the favorable photometric values) which means, as we stated before, that before a careful photometric evaluation is possible and meaningful, we must have a screen reasonably free from other disqualifying characteristics.

The next two figures illustrate some of the characteristics of a molded plastic fresnel lens type of screen. The sample supplied to us was intended for television projection. One side of this screen is formed of fine concentric prismatic rings in a typical fresnel lens arrangement. The other side is provided with a fine ribbed structure which imparts an asymmetric scattering characteristic to the screen which is properly intended to enhance the horizontal distribution

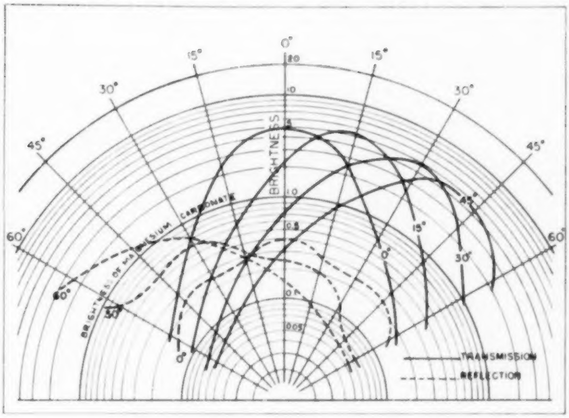


Fig. 14. Molded Fresnel lens type screen; measurements in horizontal plane through center.

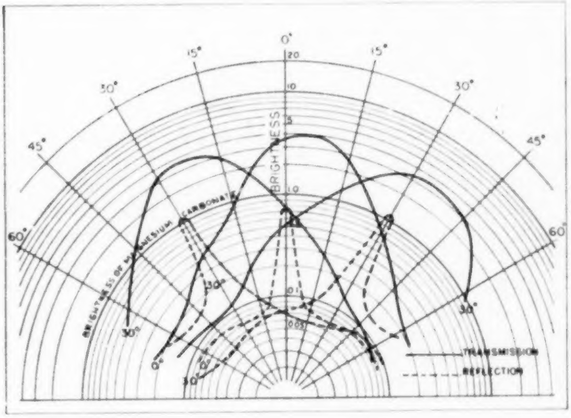


Fig. 15. Molded Fresnel lens type screen; measurements in vertical plane near edge.

at the expense of the vertical distribution, as well as to conceal the ring structure. Figure 14 represents measurements taken at the optical center of this screen along a horizontal meridian, with the ribbed structure vertical. The transmissive brightness curves are surprisingly regular and almost identical with those of some of the screens previously shown. The reflective brightness curves indicate a considerable amount of specular reflection which is observable particularly at large angles of incidence. Figure 15 represents measurements taken near the edge of the same screen along a vertical meridian. The directive effect of the fresnel structure is clearly evident in the three transmission curves illustrated, as a displacement of approximately 7° toward the optical center of the screen at all angles of incidence. This displacement is not, however, evident in the reflection curves because reflection occurs principally off of the ribbed side of the screen. The very pronounced specular reflection exhibited is the result of longitudinal cylindrical reflection from the ribbed surface of the screen when the longitudinal axis of the ribs is in the viewing

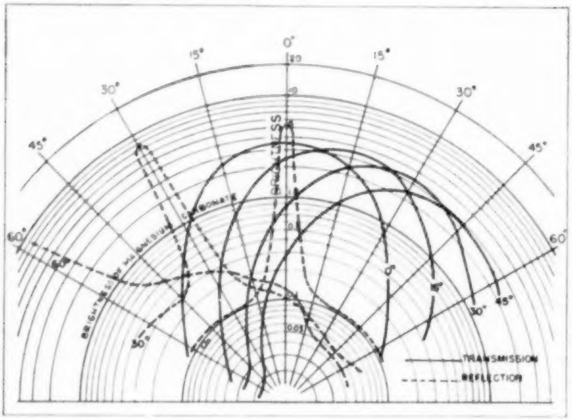


Fig. 16. **Antireflection coated opal glass screen.**

meridian. The photometric performance of this screen is not particularly impressive as compared to simpler types of rear-projection screens, but the possibilities inherent in controlled asymmetric diffusion, made use of to some extent in this screen, are suggestive.

Figure 16 illustrates the performance of a sample rear-projection screen made available to us and consisting of what appears to be an antireflection coated flashed opal glass sandwich. This screen is characterized by an unusually large and broad transmissive brightness distribution and a very low reflectance of almost cosine law distribution except at specular angles, at which points the gloss, despite the antireflection coating, is very pronounced. This screen would be very desirable for its photometric properties but unfortunately, the high contrast implied by the data is vitiated by the excessive halation and transillumination through the thick opal glass sandwich. The resolution of this screen at angles other than the normal viewing angle rapidly deteriorates because of the depth of the diffusing layer.

In the above description of some of the many rear-projection screens we have been permitted to examine we have only briefly alluded to the comparative merits of the screens. We all know, of course, that there is no such thing as a "best" screen. We can only seek the best screen for any given application. Some theaters require a matte screen with almost cosine law distribution; other houses are very narrow and benefit from the greater brightness realizable from screens having a narrower distribution angle. Photometrically the best screen for any given application would appear to be the one having a uniform brightness distribution over only the required viewing angle. The vertical viewing angle of such a screen would desirably be less than the horizontal one. Such a screen would also inherently tend to be the brightest screen for the application. Naturally, no screen can be found which will have uniform brightness over a specified distribution angle and then fall off rapidly to zero brightness. However, it is not beyond the bounds of possibility that a screen will yet be tailor-made to meet such specifications. The extent to which a screen departs from these conditions determines its departure from maximum efficiency, but specifications governing this fall within the province of standards committees. We shall concern ourselves only with what has been done and with what can be done.

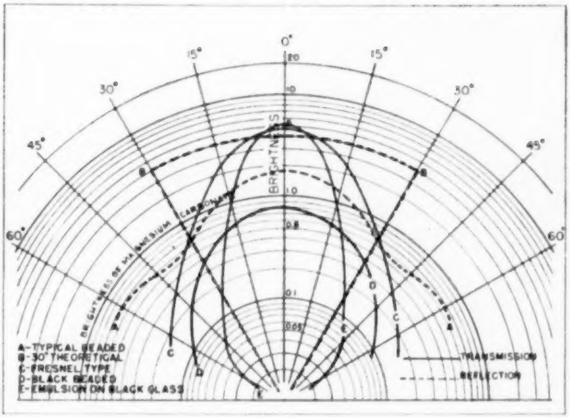


Fig. 17. Comparison of typical rear-projection screen with a beaded screen and with a hypothetical screen of 100% efficiency over a 30° angle of view.

Figure 17 gives comparative brightness curves, taken at normal projection incidence, for three of the better rear-projection screens whose complete curves have already been shown. In order to provide a basis for the comparison there are also included curves for a typical beaded screen and for a hypothetical screen of 100% efficiency whose theoretical distribution is confined to 30° from the normal.

These curves reveal some interesting facts. With the exception of screen (D) (black beaded) none of the rear-projection screens, and this is true as well of screens not included in Fig. 17, have as good a brightness distribution or freedom from "hot spot" as the ordinary beaded screen, yet beaded screens are known for their marked directional distribution. The only screen free from an objectionable "hot spot" is screen (D) which is very inferior in brightness. If these screens are now compared with the theoretical possibilities held forth by curve (B) it will at once be apparent how far we have yet to go in the direction of a really good rear-projection screen.

In order to illustrate the possibilities inherent in controlled brightness distribution we have for Fig. 18 drawn curves similar to curve (B) of the previous figure to illustrate the brightness of screens whose possible theoretical brightness has been computed mathematically by evaluating the surface integral of the light intensity function of a Lambert-type diffuser of various specified symmetrical and asymmetrical distribution patterns. Curve (A), for the purpose of comparison, is that of a typical beaded screen. It should be noted that these curves are divided into vertical and horizontal quadrants, and that curve (A) is of course symmetrical through both quadrants. Curves (B) and (C) are for hypothetical screens whose distribution is confined to 45° and 30° from the normal, respectively. These screens, despite their specified uniform brightness over the entire specified distribution angle, would be two and four times as bright as a standard cosine law diffuser. If, as is clearly indicated in most projection situations, the vertical distribution be limited, even greater brightness gains could be achieved. Curves (D), (E) and (F) are for hypothetical screens whose horizontal distribution is confined to 45°, 45° and 40°, respectively, to each side of the vertical meridian, and whose vertical distribution is confined to $22\frac{1}{2}°$, 15° and $12\frac{1}{2}°$, respectively, above and below the horizontal meridian. In

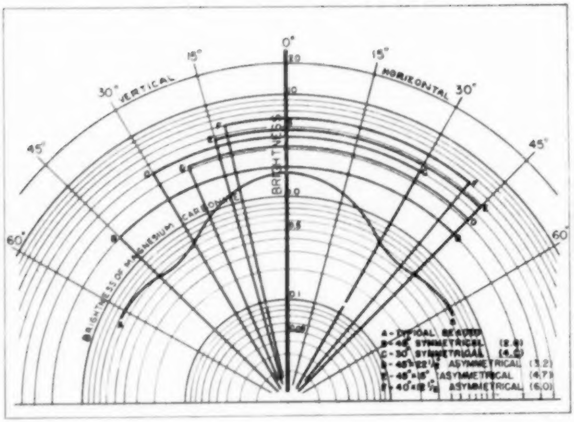


Fig. 18. Curves illustrating the theoretical brightness gains of engineered screens of variously assigned angles of view.

other words, they have a rectangular distribution pattern. These screens could attain the astonishing brightness of, respectively, 3.2, 4.7 and 6.0 times the brightness of the standard without fall-off from or hot-spot at the center.

Returning now to the problem of an objective evaluation of rear-projection screens, we have shown that a single term such as "brightness gain" does not convey sufficient information. It may indeed misinform because it is the result of measurement at a singular point, the hot-spot. Two screens might have the same brightness characteristics at all viewing angles except that one has a narrow hot-spot at the normal viewing angle, and yet they would be rated as being very different in effective brightness gain. The curves of reflected and transmitted brightness do give complete and objective photometric information, but they require some analysis and a bit of experience in their application. A single curve, which would be representative of the performance of the screen under actual viewing conditions, and from which such information as the available contrast range, the presence of hot-spots, the existence of gloss or specular reflection and the amount of tolerable ambient illumination can be ascertained by inspection, would be most desirable for objective photometric evaluation.

Figure 19 illustrates a projection arrangement for front or rear projection in which the projection angle and the viewing angle are maintained equal, and in which ambient light is assumed to fall upon the screen at an angle of 30°. This is an arbitrary arrangement, yet it will be seen to be not untypical of actual rear-projection conditions. The justification for this selection is the fact that the photometric factors involved change only gradually and without marked singularities so that the behavior of a screen in any arbitrary arrangement is representative of its behavior within a considerable range from the arbitrary arrangement selected.

Using the measurements made upon the screens previously discussed we have computed the transmissive or reflective brightness ratios for the corresponding projection and viewing angles illustrated in the diagram, and the reflective brightness ratios for the corresponding viewing angles at 30° left ambient light incidence. The total brightness of the screen as viewed at any designated angle is then equal to the sum of the projected and ambient brightness. This is the maximum attainable highlight brightness. The brightness of the screen at any

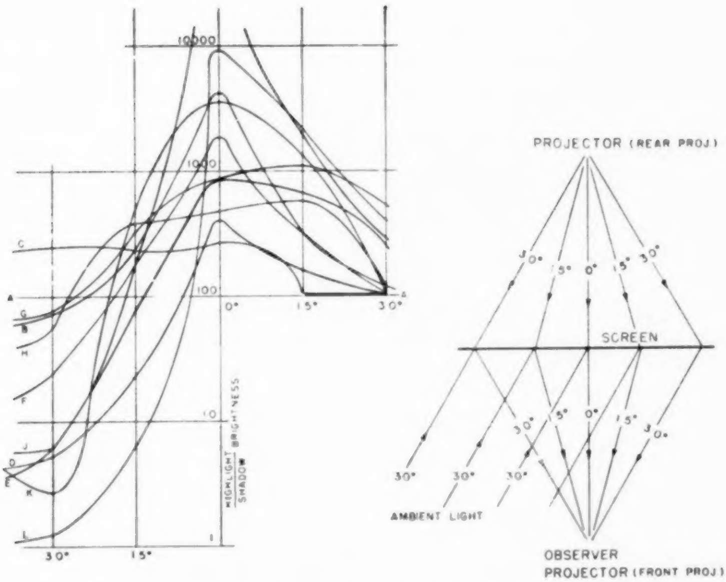


Fig. 19. Contrast profiles. The projection diagram illustrates the basis of the measurements from which the curves were calculated.

viewing angle due to the ambient illumination alone is equal to the minimum shadow brightness. The quotient of the maximum highlight brightness divided by the minimum shadow brightness represents the maximum picture contrast range available, regardless of the contrast of the print being projected. If the maximum available picture contrast is plotted versus the screen viewing angle, a curve results which we choose to call the "contrast profile." The contrast profile reveals a wealth of data regarding not only the available contrast at any point on the screen, but information as to singularities such as gloss or hot-spots.

The contrast profile is plotted on a logarithmic base. The contrast of a screen whose reflective and transmissive brightness ratios are equal is taken as 100. On this basis the line A-A at the 100 ordinate also represents a perfect cosine law screen because of the well-known fact that the reflectivity of cosine law diffusers is always equal at the same viewing angle, regardless of the incident projection angle. A little consideration will reveal that the contrast profile may be read to advantage in another manner. If the reference line A-A is designated as unity (1.0) instead of 100, then the values of the ordinate may be read as the ratio by which the ambient light upon the screen may be increased over that permissible upon a cosine law screen and yet maintain the same picture contrast. Thus the contrast profile of a screen which reads above 1000 or (10.0) at any point means that the screen at that point could be subjected to 10 times the ambient illumination of a perfect (cosine law) diffusing screen and still have as good or better picture contrast.

It is apparent that most of the contrast profiles show peaks at the normal viewing angle. These peaks are simply

the result of the increase in the numerator of the contrast ratio fraction, caused by the high direct transmission or hot-spot brightness at the normal viewing angle. The size of the peaks is a measure of the severity of the hot-spot, and a ratio between the ordinate heights of the hot-spot peaks, which is easily found because of the logarithmic plot, permits of a quick realistic comparison.

Most of the screens exhibit a marked contrast profile drop in the vicinity of 30° left viewing angle, which is a symptom of the specular reflection of the 30° incident ambient light. It is characteristic of most rear-projection screens that they are worse than front-projection screens in this respect. A desirable rule to follow in rear projection is therefore to avoid the incidence of ambient light at angles within the specular range.

Adverting briefly to the individual contrast profiles, the letters identify screens according to the following description:

A. Cosine law diffuser, Fig. 4
B. Plastic rear projection, Fig. 8
C. Beaded front projection, Fig. 7
D. Aluminized stereo projection, Fig. 6
E. Emulsion on black glass, rear projection, Fig. 13
F. Fresnel type, rear projection, Fig. 14
G. Black beaded coating on glass, rear projection, Fig. 10
H. Plastic black, rear projection, Fig. 9
J. Emulsion on opal glass, rear projection, Fig. 12
K. Anti-reflection coated opal glass, rear projection, Fig. 16
L. Dark black beaded coating on plastic, rear projection, Fig. 11

A few of the curves are of especial interest as illustrations of the properties of the screens they describe.

Curve C illustrates the excellent contrast under ambient illumination realizable with beaded reflecting screens. That this is the result of the unique directive properties of beaded screens is proved by the anomalous contrast low from 15° to 30° right viewing angle, with no low point at all due to ordinary specular ambient light reflection at 30° left viewing angle.

Curve H, a black plastic rear-projection screen, is an example of a good rear-projection screen with moderately high contrast over a wide viewing angle range, and with relatively low specular reflection of ambient light.

Curves K and L are examples of screens whose contrast profile takes an extremely sharp dip as a result of the bad gloss of the screen.

We have presented numerous data on existing screens and we have alluded to the possibilities latent in screens engineered to conform to certain restrictions on the viewing angle, with particular reference to asymmetric light distribution favoring the horizontal viewing angle at the expense of the vertical. We shall now describe some preliminary work done to realize these possibilities, based on earlier work by one of the authors[10] on screens having asymmetric brightness distribution.

Our experimental work on screens is based on the following premises. Most screens depend on random refractive or reflective scattering of light by microscopic granules or surface irregularities, and their brightness curves can be regarded as optical probability curves. In order to obtain controlled diffusion it is necessary to secure, not random scattering, but controlled direction of the projected light. In other words, the optical performance of the screen must be the result of deliberate design and computation, much as lens systems are the result of design and computation. We propose that the screen be treated as an optical instrument, not as a random scatterer of light rays, and we feel that in this direction is possible the greatest advance in screen development. Needless to say, only a complete goniophotometric specification of such a screen will specify its desirable properties, for no single term such as brightness gain

Fig. 20. Experimental outdoor theater screen curves taken in the vertical, horizontal and 10° off horizontal plane.

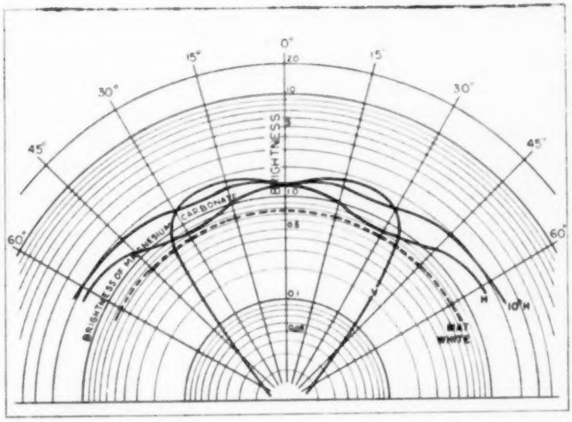
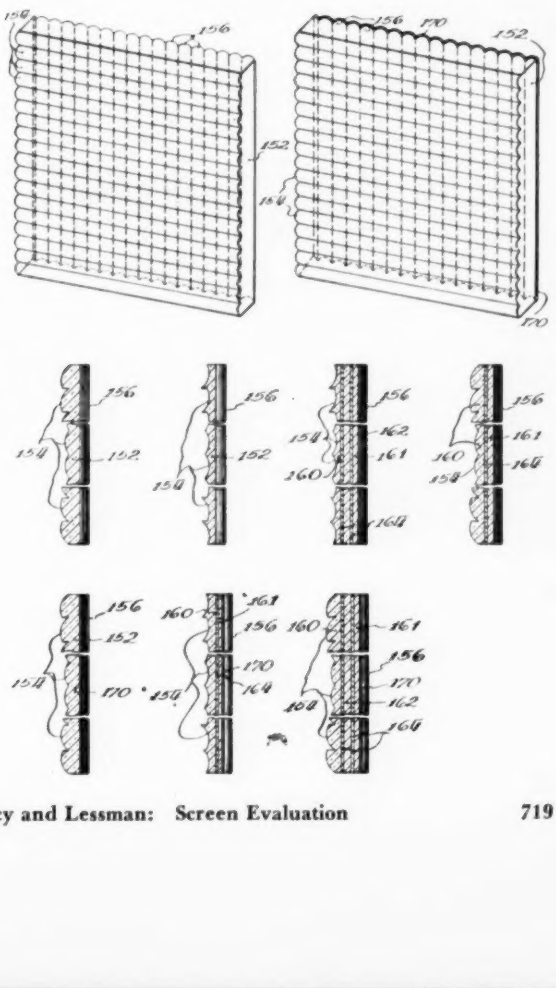


Fig. 21. Optically engineered screens as disclosed in Lessman Patent No. 2,326,042 (1943).



nor any single coefficient designating its general departure from cosine law distribution can designate such controlled asymmetric diffusion.

The performance of an experimental screen made up from available materials without the benefit of refined design is illustrated in Fig. 20. The resolution of this screen, due to the large size of the diffusing elements, makes it suitable only for large projections such as outdoor theater screens, but the brightness gains realized confirm the soundness of the approach employed.

The curves are shown compared to the brightness of one of the best matte white screens obtainable. The brightness of the screen in the horizontal meridian and along a 10° off horizontal meridian is about 250% greater than the matte white screen all the way out to 60° from the normal viewing angle. The brightness along the vertical meridian is maintained at about 250% of the comparison screen out to 30° from the normal viewing angle and then falls off sharply almost to zero. These brightness gains are startling yet they can be bettered by properly designing this screen for the more limited horizontal angle desirable for this application.

The structure of this screen is illustrated in Fig. 21. The experimental screen consists of a piece of glass ribbed horizontally on the front face and ribbed vertically and silvered on the rear face. The curvature of the ribs is the design factor controlling the horizontal and vertical diffusion, and since the path of the projected light rays incident on the screen can be computed through the several refractions and reflections involved, the performance of the screen, like that of any other optical instrument, is completely predetermined.

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An Apparatus for Aperture-Response Testing of Large Schmidt-Type Projection Optical Systems

By D. J. PARKER, S. W. JOHNSON and L. T. SACHTLEBEN

An interpretation of the aperture-response concept as it applies to lenses or optical systems is followed by a description of an apparatus with which large Schmidt-type projection optical systems may be tested. The apparatus is adapted to present continuously the response curve on an oscilloscope, where it may be photographed against a grid for further study. The optical system may be tested for response to both radial and tangential line detail, in field zones that extend out to half the normal raster diagonal from the center.

THE PROBLEM of measuring the ability of a lens or optical system to produce a good image is an old one. Evaluations have generally been based on the ability of the lens to produce an image of fine parallel line detail. The means employed have usually consisted of observing the image at high magnification with a microscope, or of photographing the lines on a sensitive emulsion. In either case, quantitative evaluation of the performance of the lens has been limited to determining the number of lines per millimeter in the image surface at which the lens failed to produce anything that could be recognized as an image of the lines.[1] This method describes the condition under which the lens completely fails to perform, and quite obviously yields little or no quantitative information about the performance of the lens in its normal range of usefulness. This was often made clearly evident by the fact that although the limiting resolution of a particular lens might be many lines per millimeter, the image would remain "soft" and of poor contrast even down to a very few lines per millimeter. In the case of some other lens, the limit of resolution might not extend out to nearly so many lines per millimeter, but below that figure, the lens might rapidly attain performance of very acceptable quality.

No new or very effective methods were brought to bear upon this problem until the late 1940's, when the papers of Herriott[2] and Schade[3] appeared.

These papers recognized that a lens

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(This paper was received October 7, 1953.)

could be evaluated by making a survey of the distribution of light in the image of the parallel line test object. If the parallel line test object has a constant contrast ratio over a large range of line widths, such a survey will provide information about any failure of contrast to remain constant in the image when line width changes, as a result of departures of lens imagery from geometrical perfection. This information is independent of any uniform stray light that the lens may originate and deliver to the plane of the image, because such stray light has only the *effect* of a change of contrast in all parts of the object by a fixed amount, and does not disturb the essential property of constancy of the contrast ratio throughout all parts of the test object.

Herriott and Schade accomplished such surveys experimentally by what amounted to passing a relatively small scanning aperture across the image of the lines and measuring the light that came through the aperture as a function of its position in the image. The ratio of the difference between maximum and minimum light passed by the aperture for one width of line to the difference for another width of line, with certain qualifying restrictions to be mentioned in a paragraph below, gives a number that is characteristic of the image-forming properties of the lines insofar as those two particular line widths are concerned. These image-forming properties are determined by the distribution of light in the image which the lens forms of an ideal point object. This distribution is, in general, symmetrical about ideal geometrical image points lying near the axis of the lens, and extends out from the ideal image point to where illuminance gradients cease to exist and uniform stray illuminance, if any, begins. Such a distribution of light constitutes the physical image.

In Schade's work, the differences described above are called the "aperture response" of the lens for the particular line widths involved. The aperture response generally decreases as line width decreases and approaches a maximum as line width becomes indefinitely increased. A curve that shows aperture response, at all line widths, as a fraction or percentage of this maximum is called the aperture-response characteristic of the lens under consideration. As noted above, the aperture response characteristic of the lens tells nothing about the general stray light that may arise in the lens. It cannot, therefore, tell the whole story of lens performance. It does, however, show the performance of the lens insofar as it is dependent upon the size of the physical image and the distribution of light in the physical image.

The causes of any general or uniform stray light contributed by the lens, may or may not affect the aperture response, accordingly as they do or do not contribute to determining the size and distribution of light in the physical image. It may be said, in general, that if the aperture response of a lens falls off very rapidly due to properties of the lens that do not contribute to uniform stray light, the lens is fundamentally faulty in design or construction. If aperture response is good, but stray light is high, removal of the stray light by coating or by eliminating mounting reflections, will surely improve the lens. Should poor aperture response be largely due to the factors that originate the stray light, such as poor surface polish which introduces diffraction defects in the imagery, their removal should greatly improve the lens.

Apart from the quality of the design and construction of the lens itself, the shape of the aperture response curve is dependent upon two conditions external to the lens. The first of these is the distribution of luminance in the lines of the test pattern, and the second is the particular focal plane in which the aperture-response measurements are made. If the distribution of luminance in the lines of the test object is sinusoidal,

a so-called sine-wave aperture-response curve for the lens will result. This curve is especially useful in the overall evaluation of the performance of electrooptical systems for the reason that analogous aperture-response curves of the sine-wave variety can be measured or otherwise determined for every element in the system even including the human eye, and when these are all multiplied together in the proper manner, a curve is obtained that evaluates the quality of the image seen by the observer. From this curve, the adequacy of the overall system may be judged. The effect upon this curve of any changes in the sine-wave aperture response of the optical system, or for that matter, of any other element in the overall system, may be judged readily, and its importance evaluated at any stage in the development of the overall system.

The relative aperture response at two different line widths is dependent upon the selected plane of focus. For example, if an optical system is focused to obtain its maximum response for relatively coarse detail, it is, in general, necessary to refocus it to obtain its maximum response for relatively fine detail. This suggests at once that the so-called "best focus" will, in general, always be a compromise that must be judged by the operator, and that his judgment of the best compromise will depend upon the character of the subject and the elements and qualities in it which the operator wishes to emphasize. This relative variation of response with focus tends to diminish as the lens approaches more closely to ideal perfection.

The design and construction of a lens directly determine the distribution of light in the image that it forms of an ideal object point. It also determines the way in which this distribution varies with focus. From the practical point of view, the "image" of an ideal object point is the physical spot of light at a selected plane of focus. The distribution of light in this spot determines the shape of the sine-wave aperture-response curve of the lens for this plane of focus.

The measurement work involved in obtaining the aperture-response curve of a lens can be simplified by using a square-wave pattern of uniformly black and uniformly white lines as a test object, and measuring average square-wave aperture response, rather than peak-to-peak square-wave aperture response. This averaging process takes into account the change in shape of the waveform preceding decrease in peak-to-peak amplitude. For practical purposes, the resulting average square-wave aperture-response curve may be converted to the corresponding sine-wave aperture-response curve. The apparatus described in this paper determines the sine-wave aperture response of a Schmidt optical system in this manner.

Figure 1 illustrates the general arrangement of the testing setup. At the right is the conventional Schmidt optical system including spherical mirror and corrector or ogee lens. Spaced from it at the left, at the distance at which the Schmidt system is designed to project a television picture, is the apparatus for introducing the square-wave test signals into the optical system. This signal generator consists of a projection lamp and optical system arranged to illuminate uniformly the ogee lens of the Schmidt optical system. The lamp and lens X of the optical system uniformly illuminate the projection lenses Y and Z, which, in turn, project lens X upon the ogee lens. The lamp and lenses are located inside a cylindrical drum with the lenses Y and Z very close to the drum in order to illuminate a limited part of the drum uniformly. This drum is rotated by a synchronous motor at 1800 rpm. The periphery of the drum is perforated with a series of groups of slots. Each pair of slots in any group is separated by an opaque bar

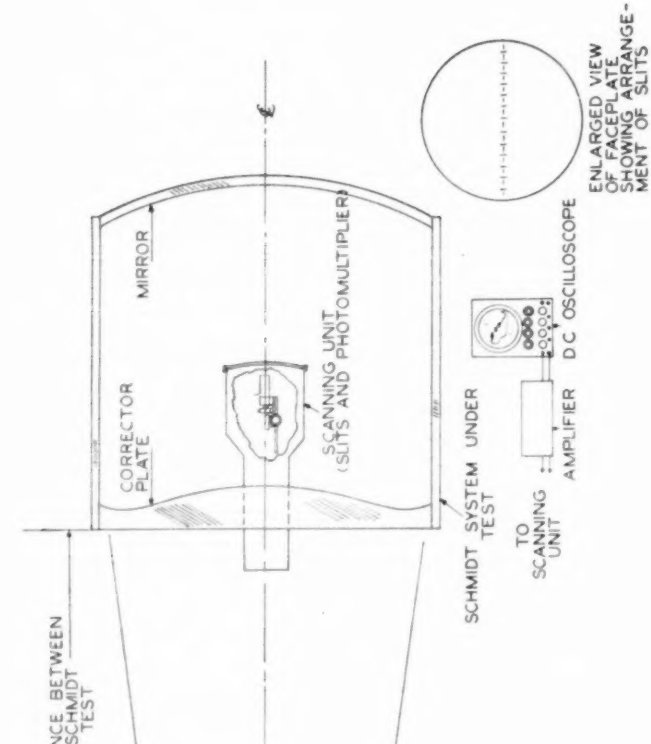

Fig. 1. Schematic of aperture-response measuring setup.

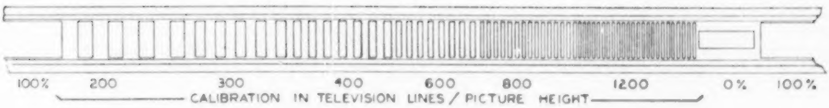

Fig. 2. Developed view of slotted periphery of scanning drum.

whose width equals the width of the slot. The slots range in width from 0.9–0.15 in. which respectively correspond to 200 television lines per picture height and 1200 lines per picture height for a 15-ft high picture. Six groups of slots are employed corresponding to 200, 300, 400, 600, 800 and 1200 television lines per picture height. Figure 2 is a developed view of the slotted surface of this drum. In addition to the groups of slots, a portion of the periphery is perforated with a long unbarred slot to provide a 100% response reference level, while another section is similarly perforated to provide a zero response reference level.

The 750-w bi-plane projection lamp used to illuminate the slots is cooled with a fan. The optical system, fan, slotted drum and synchronous motor are adjustably mounted so that the rotation axis may be located in either a horizontal or a vertical plane. The assembly may also be tilted to project the light beam horizontally or upward at a convenient angle. The drum assembly is turret-mounted on top of a cabinet which rolls on casters and may be set astride a guide rail fastened to the floor of the test room. By moving the drum assembly along the guide rail and reorienting the turret to keep the beam of light projected into the Schmidt, the performance of the optical system may be tested at any zone of its normal field. By setting the drum axis in a horizontal and then in a vertical plane, performance difference due to astigmatism may be observed in the outlying parts of the field. The signal generator assembly is shown in Fig. 3.

Referring once more to Fig. 1, the kinescope in the Schmidt optical system on the right is replaced by an opaque kinescope faceplate that is provided with a series of very narrow transparent slits, arranged along the diameter of its concave surface. These slits are arranged alternately in horizontal and vertical positions. The face plate is secured to the end of a mechanical assembly that is mounted in the optical system in the normal position of the kinescope. This assembly mounts a multiplier phototube and a mechanism for positioning the phototube behind any slit on the faceplate. The faceplate and phototube assembly are shown in Fig. 4, and this assembly is shown mounted in operating position in the Schmidt optical system in Fig. 5.

By the principle of optical reversibility, the slots in the spinning drum are focused by the Schmidt optical system on the concave surface of the faceplate. By suitably orienting and positioning all of the elements concerned, the slots may be imaged upon the central slit of the group or upon any slit in the outlying part of the field of the optical system. The images of the slots move at right angles to their long edges which must be set parallel to the slit. Several drum slots are imaged simultaneously in the vicinity of the slit and the relative motion between this image and the slit enables the slit to function as a scanning aperture to survey the distribution of light in the image. If the slits are distributed along a horizontal diameter of the faceplate, measurements made with the series of vertical slits will then give a series of aperture-response curves for the tangential image surface of the optical system. If the scanning is done with the horizontal slits, the resulting

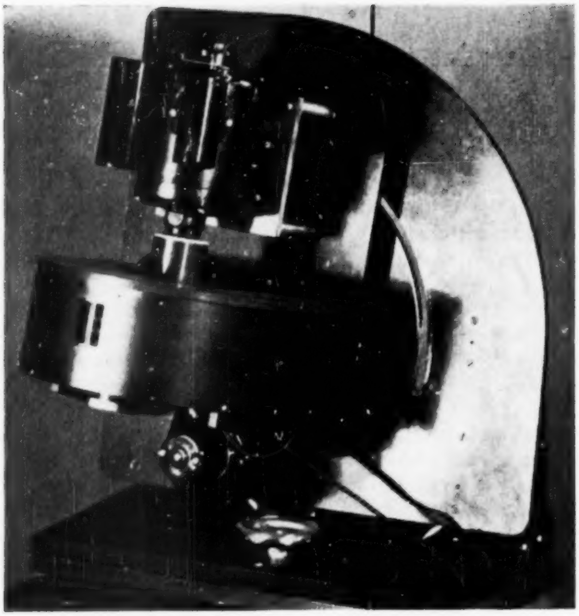

Fig. 3. Signal generator assembly.

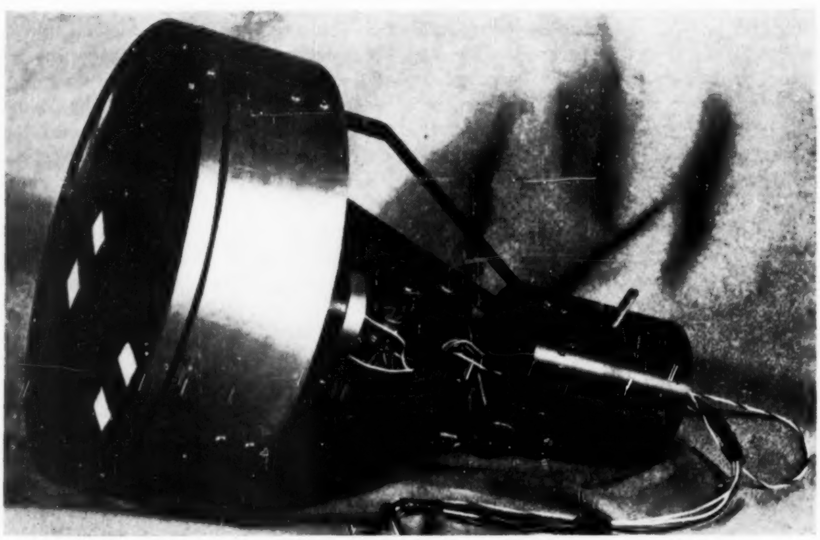

Fig. 4. Faceplate and phototube assembly.

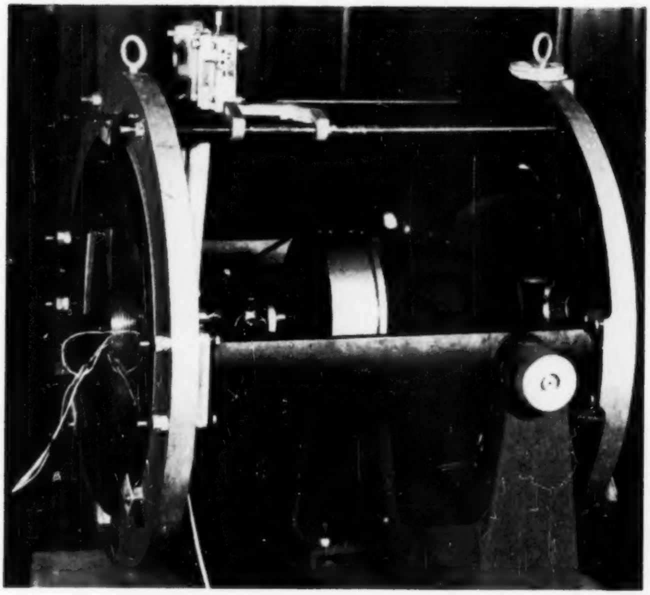

Fig. 5. Faceplate and phototube assembly mounted in operating position in the optical system.

response curves will apply to the sagittal image surface of the system.

The slits are about $\frac{1}{1000}$ of an inch wide and are a little longer than the images of the slots. The slits can receive light from the entire effective aperture of the optical system, and no other optics that might introduce effects of their own are involved in the tests. A number 5819 multiplier phototube is used as a photo-receptor and is provided with a battery power supply. Figure 6 shows the electrical circuit of the measuring system. The output of the phototube is coupled by a cathode follower tube to an amplifier with a flat response over a frequency range exceeding the 10th harmonic of the fundamental frequency corresponding to 1200 lines per picture height. The amplifier output is rectified to provide a voltage that is proportional to the average d-c value of the light pulses that are passed by the slit. The smaller unbarred slot passes half as much light to the slit as any of the slots in the barred section of the drum. When this single-pulse of relatively low frequency is impressed on the electrical circuit, it develops the same d-c voltage at its output terminals that would be developed by a barred section of the drum if the bars were so fine that they would not produce any variations in light passing the slit, due to a total loss of contrast in the image. This determines an output voltage that corresponds to zero square-wave aperture response. The larger unbarred section of the drum passes twice as much light to the slit, or an amount equal to that passed to the slit by any slot in the barred section of the drum. This develops voltage at the electrical circuit output that equals the voltage that would be developed by the barred sections of the

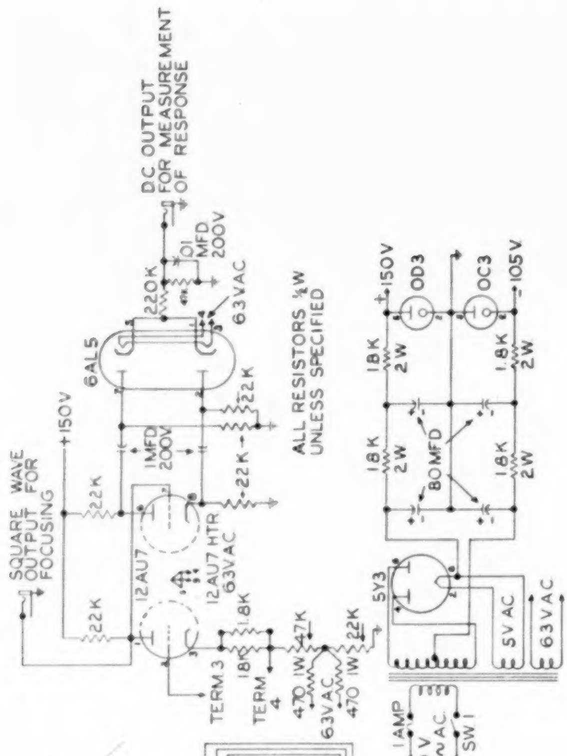

Fig. 6. Electrical circuit of the aperture-response measuring system.

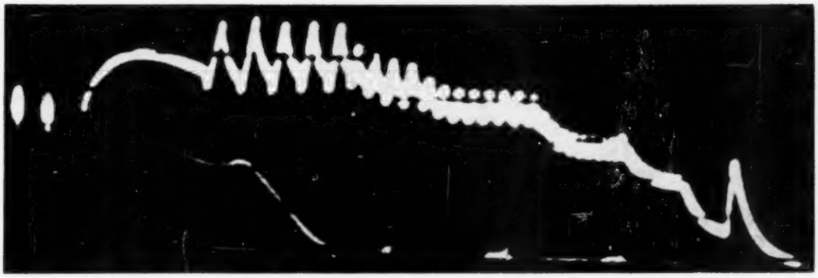

Fig. 7. Aperture-response curve as it appears on the oscilloscope.

drum were the optical system capable of producing a perfect image. This voltage is then the 100% square-wave aperture-response reference.

The output voltages developed during the passage of the various sections of the drum are impressed upon a d-c oscilloscope whose horizontal sweep is synchronized to the same frequency that drives the synchronous drum motor. A stationary trace is developed on the face of the oscilloscope in the form of a series of steps whose distances above the zero response level are proportional to the square-wave aperture response at the various numbers of television lines per picture height that correspond to the groups of slots in the drum. An edge-lighted grid may be placed in front of the oscilloscope and both grid and response trace photographed for later evaluation of the results. The combined spectral response of the 5819 multiplier phototube and the tungsten light emission gives a sensitivity curve that extends from 3800 A to 6500 A, peaked at about 5200 A. This reasonably approximates visual response for the purpose of evaluating image quality in a projection optical system of this type. It has been found advisable to place an infrared absorbing filter in the light beam near the rotating drum to protect the slits from damage due to heating. The cooling fan normally used to direct air through the central aperture of the spherical mirror is also used for this purpose. Light is delivered to the slits by the optical system at about $f/0.85$ and rather high temperatures can be developed locally in the neighborhood of the slits.

Figure 7 is a photograph of one of the response curves on the face of the oscilloscope. When the sine-wave aperture-response curve is derived from the data furnished by this curve, the result is in reasonably good agreement with a similar response curve computed from measurements made on the distribution of light in the projected image of a very small light source located at the concave surface of the kinescope faceplate. A figure of merit may be derived from the sine-wave aperture response curve if a square topped curve is plotted having 100% response at all line numbers and extending out far enough to include the same area that is included under the squared sine-wave aperture-response curve. The figure of merit (N_e, or equivalent pass-band, in Schade's[4] terminology) is the line number at cutoff for this derived curve.

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Compact High-Output Engine-Generator Set for Lighting Motion-Picture and TV Locations

By M. A. HANKINS and PETER MOLE

Since the earliest use of artificial light on motion-picture locations, portable engine-driven lighting-power sources have been needed. This paper describes the design features and performance characteristics of a new 650-amp, 120-v, d-c, engine-generator set which is much smaller and lighter in proportion to its power output than any of the previous equipments.

In the design of engine-generator equipment for supplying power on locations many factors must be judiciously considered in order to provide adequate "efficiency of utilization." Of prime importance is the balance of maximum power vs. flexibility and portability.

As an example, a single 150-kw plant,[1] now widely used in the industry, will satisfy the overall power requirements for most locations. The Mole-1400[2] is such a plant but, although it is more portable than any other of equal capacity, it is 118 in. long × 54 in. wide × 73 in. high and weighs 11,660 lb. The trend toward an increase in the amount of work at remote locations has resulted in the need for more portable and flexible units to supplement the comparatively larger types.

A considerable handling and transportation advantage would result if power capacity equivalent to the single 150-kw plant could be produced by two smaller packages with a combined weight appreciably below that of the larger single unit. The smaller plants could be loaded on or trailed behind the equipment trucks, or even be carried by the same truck upon which lighting equipment is mounted during operation. In emergencies a plant of sufficiently small dimensions and weight may be transported to location by air.

By utilizing two smaller units electrically connected for 3-wire distribution, a saving of 30% in cable is effected over the 2-wire system of the larger plant.

The larger plant is at times operated at no more than half capacity on locations where full capacity is required only for peek demand. If two smaller plants were employed only one need be operated during the slack periods.

A shut-down of the larger plant, when it is the sole source of power, may bring production to a standstill, whereas, if two smaller units are operating and one of them requires attention it may be

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(This paper was received October 1, 1953.)

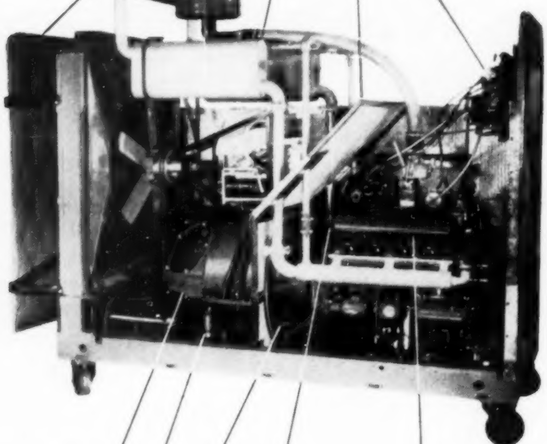

Fig. 1. The Mole-700 Engine-Generator, right side, with top and side removed.

possible to rearrange production so work can be continued with one machine.

After lengthy discussions with those in the industry who use the equipment, the Mole-Richardson Co. proceeded with the development of a compact, extremely portable power plant having about half the capacity of the Mole-1400 unit.

Since the prime objective was the reduction of size and weight as compared to previous designs, a survey was conducted to determine the maximum, practical operating speed for both engine and generator. This is doubly important because the weight per kilowatt of delivered power may be reduced as the rotating speed is increased.

It was learned that the General Electric Co. could produce a special d-c generator of the desired capacity with an operating speed as high as 3,600 rpm which is higher than normally encountered in d-c generator requipment of this capacity.

After a thorough study of the various types of available engines, the Cadillac automotive engine appeared to be the most promising. This choice was made after discussion of the engine's performance characteristics and the proposed application with Cadillac engineers in Detroit.

To verify the conclusions which had been reached, one engine was purchased and installed in an existing power plant in the Mole-Richardson Co.'s rental department. Its performance under actual

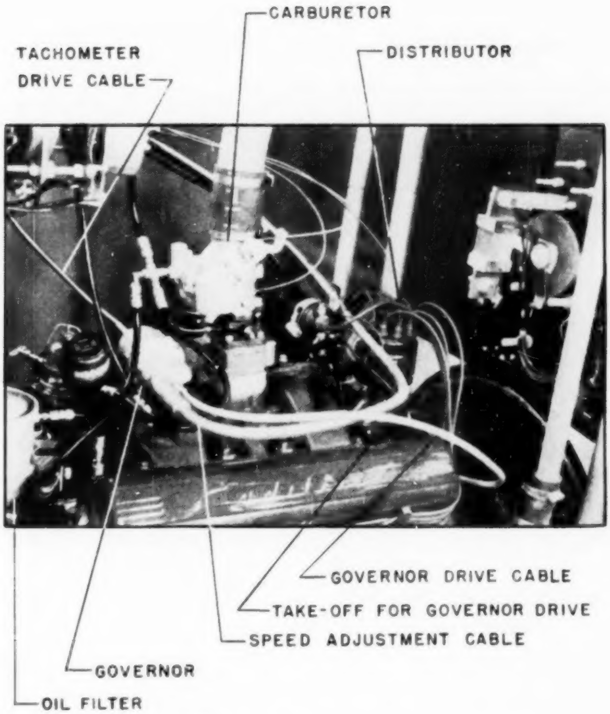

Fig. 2. Top of engine.

operating conditions was carefully studied for a period of eight months before deciding to proceed with the development.

The generator (Fig. 1) with performance matching the speed-horsepower characteristics of the Cadillac engine was developed through the combined efforts of General Electric and Mole-Richardson engineers. In the design, precautions were taken to provide more generator capacity than the Cadillac engine could mechanically deliver in order to prevent possible damage to the generator from overload.

It is a 2-wire generator rated at 650 amp, 125 v, d-c, for duty cycles normally encountered in location service. Its rated speed ranges from 2,800 to 3,200 rpm, which corresponds to a good operating region on the Cadillac speed-power curve. It is a single-bearing machine with class B insulation throughout. It is approximately flat compounded with the shunt field suitable for automatic voltage regulation. The weight of the generator is only 1,050 lb as compared to approximately 2,000 lb for commercially rated, lower-speed machines of equivalent capacity. The ripple voltage is less than $\frac{1}{2}$ of 1% of rated voltage, a feature which limits the emission of objectionable hum of arc lamps on the set.

The 8-cylinder, 90°, V-Type Cadillac engine is rated at 160 hp at 3,800 rpm and weighs 785 lb. For the first time this development permitted the use of an engine which is smaller and of less weight than the generator which it drives.

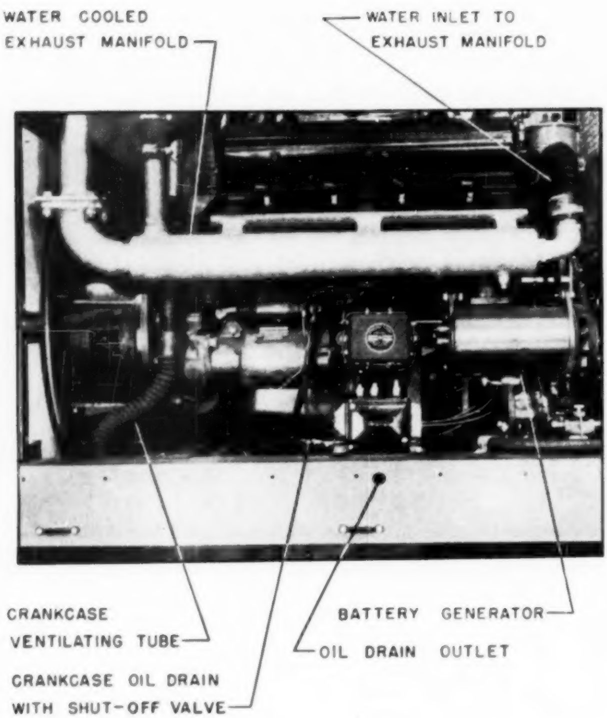

Fig. 3. Right side of engine.

Because there is no commercially available engine which can be applied to a motion-picture power plant without modification it was necessary to make the following revisions on the Cadillac motor:

1. Carburetor replaced by dual down-draft industrial type (Fig. 2).
2. Governor added to adjust and maintain speed.
3. Mechanical take-off device assembled beneath distributor for governor drive.
4. Oil filter added.
5. Exhaust manifold castings replaced by water-jacketed exhaust manifolds of Mole-Richardson design (Fig. 3).
6. Water-pump casting modified to divert cooling water through water-jacketed exhaust manifolds.
7. Battery generator relocated.
8. Oil drain line with shut-off valve installed.
9. Crankcase ventilating tube added for stationary application.
10. Electric fuel pump installed to assist mechanical fuel pump in maintaining adequate pressure at carburetor (Fig. 4).
11. Overspeed governor of Mole-Richardson design assembled on crankshaft to interrupt ignition circuit in the event of excess speed.
12. Fuel filter added.
13. Carburetor air cleaner relocated for access to cool air (Fig. 1).
14. Water temperature safety switch

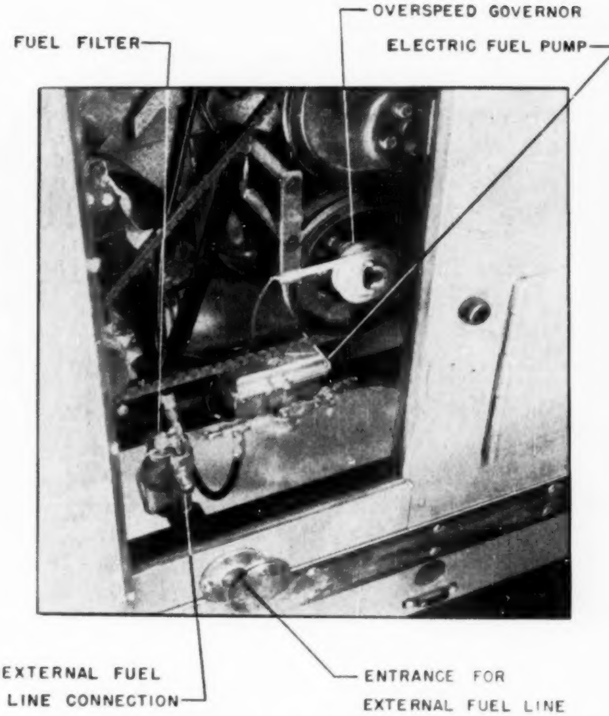

Fig. 4. Lower right front of engine.

installed in engine block to warn operator in the event of overheating.

15. Oil pressure safety switch added to interrupt ignition circuit should loss of oil pressure occur.

16. Hydra-matic flywheel replaced with standard type machined to accommodate generator coupling.

17. Engine fan removed.

One end of the armature of the single bearing generator is coupled to and supported by the engine flywheel. The coupling is of a flexible laminated steel-disk type with no deteriorating parts and has proven itself by application in other fields. A welded steel adapter housing (Fig. 1) was designed to mount the generator frame to the engine bell housing with rabbet fits to assure alignment of the axes of rotation of engine crankshaft and generator armature.

The engine and generator coupled together as an integral mechanical unit is supported on a welded steel box section main base frame by four rubber mountings to minimize transmission of vibrations to the base and enclosing structure.

The housing (Fig. 5) is made of fireproof materials throughout and designed for convenient operation and maintenance. It is constructed in sections: one end, two sides and one top for disassembly convenience at times of major overhaul. Five access doors are provided for routine inspection and maintenance. The operator's control panel, electrical outlet bus-bar compartment, and external fuel line entrance is located

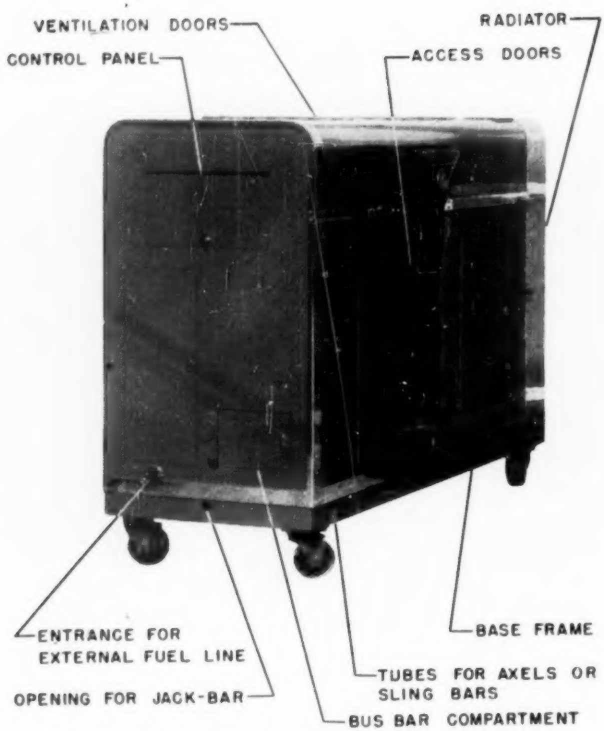

Fig. 5. Mole-700 Power Plant, closed for transport.

on one end-section of the enclosure. The opposite end of the enclosure is formed by the radiator. With the top and sides removed (Fig. 6) the working parts are exposed, yet the plant may be operated for test.

The heat is removed from the engine cooling water by the combination of a large tube and fin radiator and fan (Fig. 7) at the generator end of the plant. The 30-in. diameter fan is belt driven from a sheave on the generator armature shaft and has six variable-pitch blades which are thermostatically controlled to automatically maintain approximately 180 F cooling water temperature. Hence, no more air is drawn through the radiator than is required for adequate engine cooling, and noise which would result from an excess air speed is prevented. A maximum air flow rate of approximately 7000 cu ft/min is sufficient for full load operation in an ambient temperature of 115 F such as might be encountered on a desert location. After the air is drawn through the radiator it is deflected by a sloping partition through adjustable door openings at the top of the enclosure (Fig. 8).

A fan on the coupling end of the generator armature draws outside air from a screened opening below the radiator through air ducts (Fig. 9) into the commutator end of the generator and exhausts it into the engine compartment, after which it passes out of the enclosure through one of the top ventilating doors.

The control panel (Fig. 10) has all of the necessary instruments, switches, etc. for control of both the engine and elec-

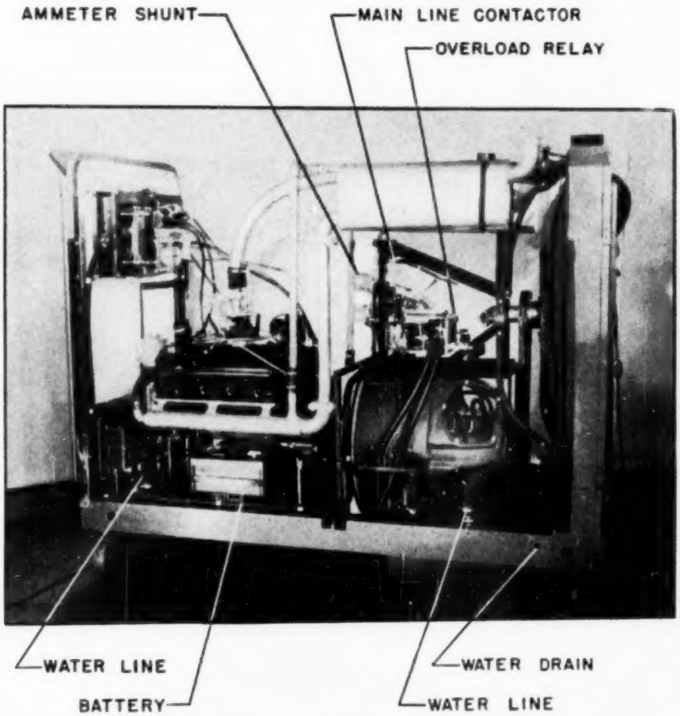

Fig. 6. Left side, with top and sides removed.

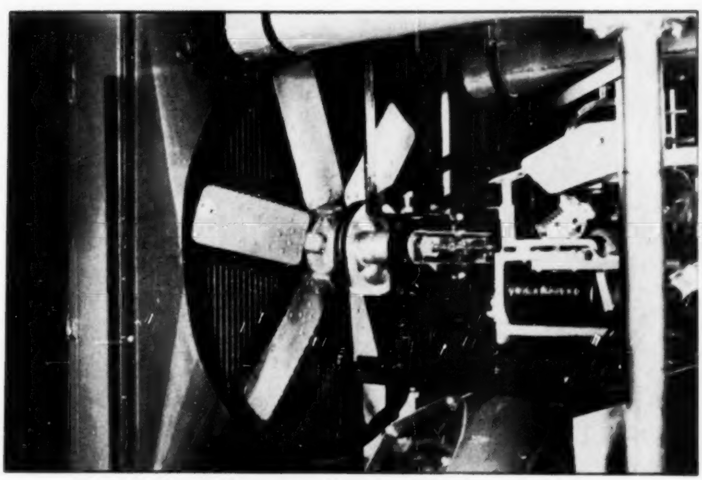

Fig. 7. Radiator and fan.

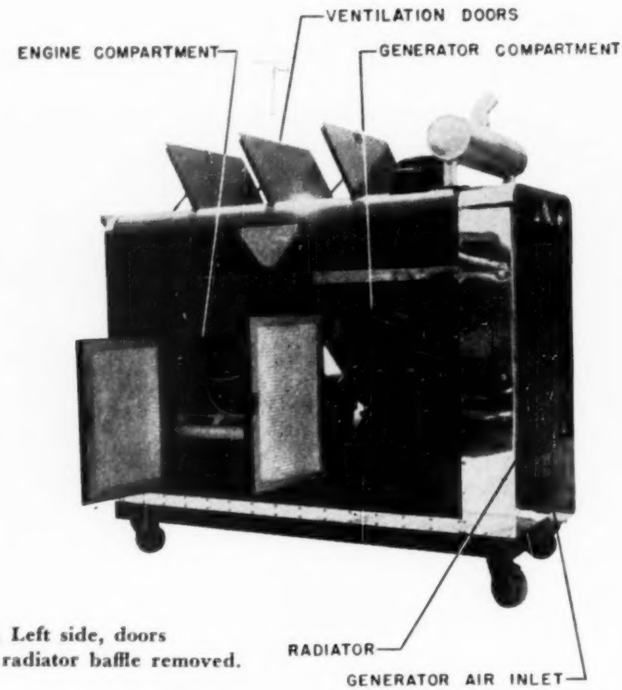

Fig. 8. Left side, doors open, radiator baffle removed.

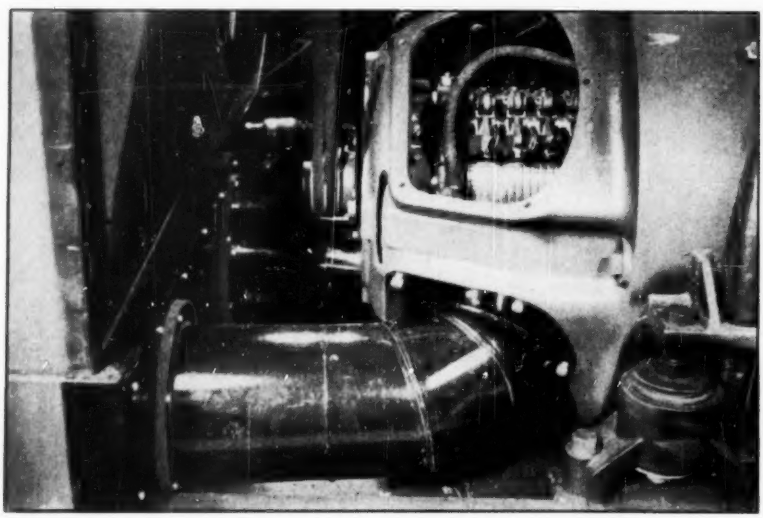

Fig. 9. Air ducts to generator.

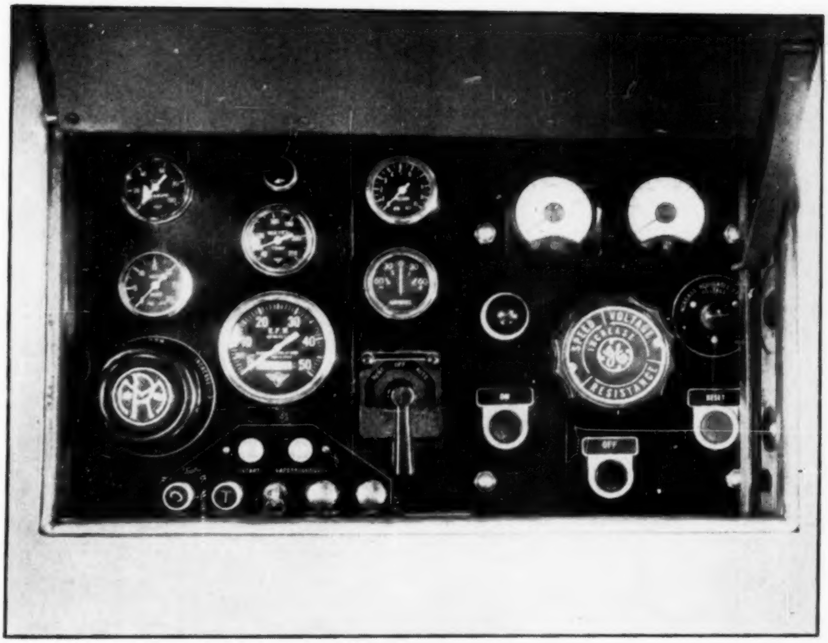

Fig. 10. Control panel.

trical power circuits. The engine controls are located on the left side of the panel and those applicable to the generator are on the right. Engine governed speed may be adjusted by setting the governor control knob. The generator voltage may be controlled either manually with a rheostat, or automatically by a voltage regulator, and the selection between the two is accomplished by positioning the field control selector switch. OFF and ON pushbuttons operate the main line contactor which controls the power-supply voltage at the bus-bar compartment.

Several safety features are provided to prevent damage to the plant. An oil-pressure switch interrupts the ignition circuit should loss of oil pressure occur, and a water temperature switch causes a warning light to glow on the control panel if the engine overheats. A centrifugal overspeed governor interrupts the ignition circuit in the event of excess speed. An overload relay causes the main line contactor to open the electrical power circuit in the event of a short-circuit in the external distribution system. Also, to protect against a failure in the thermostatic control of the pitch of the radiator fan blades, a mechanical means is provided to lock the blades in full pitch.

Silencing of an engine generator set for motion-picture and television location work entails a compromise between the degree of noise reduction and portability. Previous experience gained with the sound insulation design of similar equipment leads to a solution which satisfies both requirements particularly well. The wall construction consists of an outer 20-gauge sheet steel skin with Minnesota Mining undercoating applied on its inner surface. A fibrous asbestos material is sprayed over the undercoating

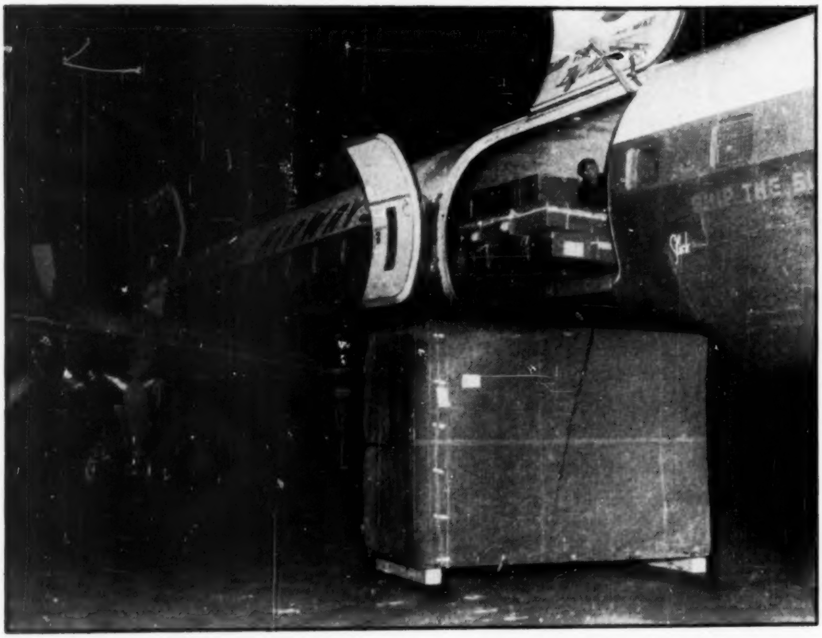

Fig. 11. Mole-700 Power Plant, prepared for air transport.

to form an additional sound absorbing layer about ¾ in. thick, and is protected by two coats of casein base paint and metal hardware cloth. The bottom of the plant is closed with covers consisting of ½ in. thick Celotex between 18-gauge steel sheets. An acoustical partition (Fig. 1) within the housing made of ½ in. thick Celotex faced on both sides by ⅛ in. thick Transite prevents engine mechanical noise from escaping through the radiatior. All access doors are gasketed. A blanketed baffle spaced a short distance in front of the radiator reduces the air and fan noise and serves as a guard against radiator damage during handling and transportation.

The engine exhaust is muffled by a series-parallel system of silencers (Fig. 1). One 3-pass muffler is connected to the exhaust of each 4-cylinder bank with their outputs joined at the input of a third muffler.

Provisions are made for a variety of types of handling and transporting the equipment (Fig. 5). Casters permit the plant to be conveniently positioned, and steel tubes pass laterally through each end of the base frame for wheel axles or sling bars. Tubular openings at the ends of the base are provided for jacks. The main base frame forms a permanent skid which may be used with rollers with casters removed, and its construction is suitable for assembly of trailer wheels, axles, springs, etc.

The resulting Mole-700 Power Plant 36 in. wide × 82 in. long × 62 in. high, weighing 4,200 lb and capable of generating 650 amp at 120 v, d-c, has a capacity heretofore unequaled with respect to size and weight. Two units are electrically equivalent to one Mole-1400 Power Plant, yet their combined weight is 3,260 lb, or 28%, lighter.

With the operator's panel, bus-bar

compartment, and connection point for fuel line at one end, the radiator at the opposite end, and the ventilation doors, engine exhaust, and carburetor air-cleaner on top, both sides of the enclosure are free of operating components. It is thereby possible for a multiplicity of plants to be positioned side by side and conveniently controlled by one operator.

The dimensions and weight of the overall unit are such that it may be readily transported by air. For example, an emergency situation was recently alleviated by flying one of the Mole-700 Power Plants overnight from Hollywood to Detroit (Fig. 11). The additional expense of air transportation is often negligible as compared to the resulting savings realized by minimizing loss of production time.

The equipment has already demonstrated its usefulness, having satisfactorily performed on numerous locations throughout the United States, Canada and Hawaii over the past several months. The application of new engineering ideas directed toward minimum size and weight has resulted in a new, useful and dependable power package more compact and flexible than any of the previous types of similar equipment.

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Glow Lamps for High-Speed Camera Timing

By H. M. FERREE

Some of the unique characteristics of glow lamps are discussed in relation to their use in high-speed photography. Physical and electrical characteristics are given.

There are, in general use, today, two types of lamps: filament lamps and electric-discharge lamps. Glow lamps belong to the discharge family and share the characteristics peculiar to this group.

For many years, glow lamps have been used as pilot lamps and indicators on various electrical devices. They have to some extent been used in photographic applications. Most recently, their usefulness has extended into the field of electronics, as circuit elements. It is felt that familiarity with some of their unique characteristics will aid in their application to high-speed photography and its related apparatus.

Runaway Characteristic

As in all electric-discharge lamps, at the instant the glow is initiated, the voltage between the electrodes drops while the current is increasing.

Without some ballasting, the current would immediately rise to a destructive value. Therefore some ballast must be provided. However, since the currents involved are very small, a small, inexpensive carbon resistor can be used.

Figure 1 shows a typical group of glow lamps. These range, in wattage, from 1/25 w to 3 w. For best all-around performance, the current density must be held to a rather critical value. As the current is increased the electrode area also must be increased. Increasing the wattage much beyond 3 w would result in electrodes of absurd size.

Some of these lamps are equipped with screw bases, some with bayonet bases and one with wire terminals only. All lamps having screw bases have the necessary ballast resistor built in. This is a safety measure. Screw-base lamps may be put into sockets supplied with 115 v. If there were no resistor in the base, violent failure would result.

Those having bayonet bases or wire terminals do not have integral ballast and a resistor of the proper value must be used in series with the lamp. Table I shows the value of resistor required to operate each lamp at its rated current.

In some applications there may be sufficient resistance or impedance in the circuit to accomplish the necessary ballasting.

Presented on October 6, 1953, at the Society's Convention at New York, by H. M. Ferree, Lamp Div., General Electric Co., Nela Park, Cleveland 12, Ohio.
(This paper was received Sept. 30, 1953.)

Starting and Maintaining Voltage

Glow lamps have a critical starting voltage. At voltages below this starting voltage, the lamp may be considered an open circuit, passing no current.

When the applied voltage is raised to the critical value the lamp starts, current flows and light is emitted.

After starting, the voltage across the electrodes drops to a lower value — the "maintaining voltage" at which it continues to operate. The maintaining voltage is of the order of 15 v below the starting voltage on d-c, while on a-c the difference is less than 5 v.

The electrode surfaces of glow lamps are, to some degree, photoelectric; they emit electrons under the influence of ambient illuminations. Therefore if the lamp is operated in total darkness, the voltage required for starting may be 20 to 50 v higher than normal.

When lamps are totally enclosed, as in the case of cameras, the starting problem is usually taken care of by simply applying the additional potential.

Since the starting voltage increases with age, when used in total darkness, some of the older lamps may fail to start. As insurance, voltages of the order of 150 should be applied.

When lamps such as the NE-51 which have no resistance in the base are used, an adjustable series resistor may be employed to regulate the lamp current. This provides more uniform exposures throughout the life of the lamp and will extend the useful lamp life.

Equivalent Circuit

When conducting, the glow lamp may be considered as a counter emf (electromotive force) in series with a resistance and in parallel with a low order of capacitance.

For purposes of calculations the counter emf may be considered the same as the maintaining voltage. Using values given in Table II, the lamp current, or the external resistance required for a given value of current, other than normal may be calculated by means of the following equation:

$$\text{Lamp current} = \frac{\text{Line volts} - \text{maintaining volts}}{\text{Internal resistance} + \text{external resistance}}$$

As indicated later this lamp current may be used to determine changes in light output as well as the order of increase or decrease in the useful life of the lamp.

Light Output

Glow lamps are relatively low efficiency lamps, averaging about 0.3 lm/w. They are, therefore, not generally considered as illuminating devices. In spite of this, since the characteristic orange-red color contrasts well with surrounding illumination, they have proven quite adequate for many indicator applications. They provide small, relatively cheap and very rugged light sources for indication, identification and under some conditions, a means of illuminating dials of instruments.

The light output of these lamps is

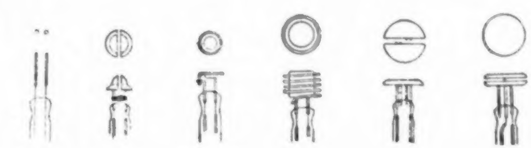
Fig. 1. A typical group of glow lamps.

Table I. Values of Resistor Required to Operate Each Lamp at Its Rated Current.

	Neon													Argon		
Watts, nominal	1/25	1/25	1/4	1/4	1/4	1/4	1/4	1/2	1	1	1	2	3	1/4	1/4	2
Volts, circuit	105–125	105–125	105–125	105–125		105–125	105–125	210–250	105–125	105–125	210–250	105–125	105–125	105–125	105–125	105–125
Nominal current, amp	0.0003	0.0003	0.002	0.002		0.002	0.002	0.002	0.012	0.012	0.005	0.018	0.030	0.030	0.0035	0.018
Bulb, clear	T-2	T-3¼	T-4½	T-4½	T-4½	T-4½	T-4½	T-4½	G-10	G-10	G-10	S-14	S-14	T-4½	T-4½	S-14
Base	Unbased (wire term.)	S.C. bay. min.	Cand. screw	D.C. bay. cand.	D.C. bay. cand.	Cand. screw	D.C. bay cand.	Cand. screw	Medium screw	D.C. bay. cand.	Medium screw	Medium screw	Medium screw	D.C. bay. cand.	Cand. screw	Medium screw
Max. overall length, in.	1 1/16	1 3/16	1 5/8	1 1/2	1 1/2	1 5/8	1 1/2	1 5/8	2 1/16	2 1/16	2 1/16	3 1/2	3 1/2	1 1/2	1 5/8	3 1/2
Electrode shape	W-11	W-11	P-3	P-3	P-3	PW-27	PW-27	PW-3	PW-5	PW-5	PW-5	P-2	P-4	P-3	P-3	P-2
Approx. starting voltage: a-c	65	65	65	65		55	55	65	60	60	60	60	60	80	80	65
Approx. starting voltage: d-c	90	90	90	90		75	75	90	85	85	85	85	85	115	115	90
Series resistance, ohms	200,000 ext.	200,000 ext.	300,000 int.	300,000 ext.		300,000 int.	300,000 ext.	100,000 int.	7500 int.	7500 ext.	33,000 int.	3500 int.	2200 int.	15,000 ext.	15,000 ext.	3500 int.
Average useful life, hr	over 25,000	over 12,000	over 7500	over 7500		5000	5000	over 7500	5000	5000	5000	8000	1000	1000	1000	3000
Lamp No.	NE-2	NE-51	NE-45	NE-48	NE-16	NE-57	NE-17	NE-58	NE-30	NE-32	NE-56	NE-34	NE-40	AR-4	AR-3	AR-1

Notes: Bulb designations—Letter indicates shape: T–tubular, G–globular or round, S–pear-shaped. Figures indicate maximum diameter in eighths of an inch.

Electrode shapes:



W-11 P-3 PW-27 PW-5 P-2 P-4

Table II. Values for Calculating Lamp Current

Lamp type	Supply volts	Starting volts	Minimum maintaining volts	Ohms Internal resistance	Ohms External resistance
S-14 3-w neon	120 a-c	53	50	310	2,200
	120 d-c	78	58	220	2,200
S-14 2-w argon	120 a-c	65	62	900	3,500
	120 d-c	90	75	730	3,500
S-14 2-w neon	120 a-c	52	49	420	3,500
	120 d-c	74	60	380	3,500
G-10 1-w neon	120 a-c	45	44	450	7,500
	120 d-c	65	57	400	7,500
T-4$\frac{1}{2}$, $\frac{1}{4}$-w neon	120 a-c	57	56	2600	30,000
	120 d-c	83	64	2200	30,000
T-4$\frac{1}{2}$, $\frac{1}{4}$-w argon	120 a-c	71	70	5500	15,000
	120 d-c	100	80	4200	15,000
T-3$\frac{1}{4}$, $\frac{1}{25}$-w neon	120 a-c	54	42	7500	200,000
	120 d-c	73	55	6000	200,000
T-2 $\frac{1}{25}$-w neon	120 a-c	54	42	7500	200,000
	120 d-c	73	55	6000	200,000

directly proportional to the current. It may therefore be increased or decreased by proper selection of the external resistance. For this reason, some of these lamps, as indicated above, do not have a built-in ballast resistor.

Useful Life

Since glow lamps have no filament, they do not burn out. As lamps, they reach the discard point by a gradual blackening of the bulb and a rise in operating voltage, both of which tend to reduce the light output. Illumination requirements will determine this point.

As circuit elements, where relatively constant voltage devices are usually required, their useful life is determined by the number of hours they may be operated before some definite change in their operating voltage takes place.

The useful life of a glow lamp is inversely proportional to, approximately, the cube of the current. Therefore, for example, doubling the lamp current will reduce the life to approximately one-eighth of normal.

The operating current of these lamps may be increased up to ten times, with a proportional increase in light output, before their electrical characteristics are seriously affected.

As indicated, by the foregoing equation, glow lamps may be operated on voltages higher than design by increasing the value of the series resistor.

Spectral Characteristics

For indicator purposes neon has been found to be the most satisfactory for filling gas. However, for some photographic purposes, lamps filled with argon are available.

Figure 2 shows the spectral characteristics of both the neon and argon lamps, showing that the radiation from neon lamps is confined to the orange-red region of the spectrum while argon radiates principally in the blue-violet and near ultraviolet regions.

High-Speed Cameras

In high-speed cameras, for purposes of analysis and identification, timing marks are usually imprinted on the film. Due to the extremely short exposure time allowable, the lamp radiation must be highly actinic and the lamp must also be capable of rapid response to the timing pulse applied to it.

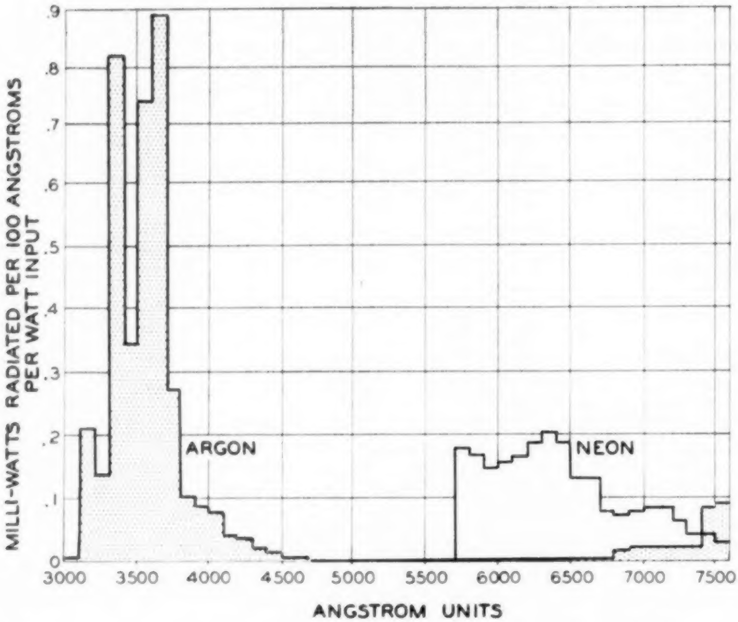


Fig. 2. Spectral characteristics of argon and neon lamps.

When black-and-white film is being used, the argon lamp has been found to meet these requirements very well.

In addition to the AR-1, AR-3 and AR-4 argon lamps shown in Fig. 1, argon lamps of the same physical dimensions as the NE-2 and NE-51 neon lamps are now available. These offer small size units which may be used when space is a consideration.

Argon lamps of the AR-4 type are used in some of the recording units employed in making radio surveys for program rating purposes. Here the lamp imprints a continuous line on the moving film, which by its position and length indicates the station tuned in and the length of time it is tuned in.

The 2-w, AR-1, argon-filled lamp is now being used in contact printers. Low wattage and small size make possible the use of a multiplicity of lamps to produce uniformly luminous areas of any size. Since there are many separate lamps they may be switched to facilitate "dodging."

The increasing use of color film in high-speed photography has brought with it the problem of producing satisfactory timing marks. The ideal light source for this purpose would be one producing white light, which would penetrate all three layers of the film. Today we do not have a gas or gas mixture which will provide a commercially practical, white glow lamp.

In the past, discharge lamps were made, containing CO_2, which did produce essentially white light. These, however, required a means of constantly replenishing the gas.

Glow lamps containing phosphors have been made; however most of the known phosphors are too slow in their response, for this application. Others which are faster present other obstacles when used in glow lamps.

Several years ago, the SMPTE High-Speed Photography Committee brought this problem to us. A neon glow lamp, operating at about five times normal loading was made available. This is the NE-66, now well known.

The timing marks produced by this lamp must be observed by reflected light. These, however, are quite easily seen and practically as satisfactory as a mark seen through the film.

Speed of Response

The rapidity with which a glow lamp may be pulsed is determined by the time required for ionization and deionization of the gas. Accurate data of this type, are not, at present, available on all types of glow lamps. However it is known that ionizing time is a function of the applied voltage, in excess of that required for starting.

In lamps of the sizes usually employed in high-speed cameras, the application of voltages 5 to 10 v in excess of starting will result in ionizing times of the order of 200 to 250 μsec, while increasing this to 50-v excess will reduce the time to, perhaps, 5 to 10 μsec. Complete deionization may require as high as 30 msec.

Other Applications

Some of the unique characteristics of glow lamps adapt them to applications where their light output is not necessarily essential.

Glow lamps provide small, low-current circuit elements for use in many electronic devices such as amplifiers, oscillators and control units which might be used in connection with high-speed cameras, television equipment or related applications.

Their use in these fields may be broken down into three basic circuits.

Figure 3A shows the basic circuit for voltage-controlled devices. Here the lamp is connected across the dividing network so that when a predetermined voltage appears across the network, a voltage equal to the starting voltage appears across the lamp. Immediately the lamp starts, current flows and light is emitted. Control of associated equipment may therefore be accomplished by the use of sensitive relays in the lamp circuit or photoelectrically.

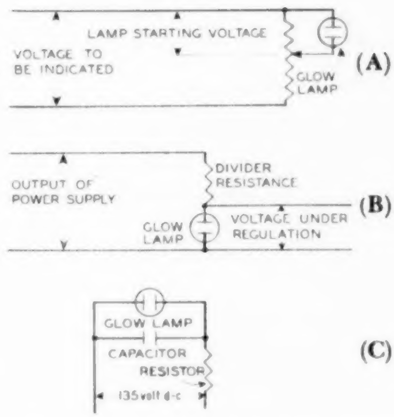


Fig. 3. Glow lamp (A) in basic circuit for voltage-controlled devices; (B) as gas diode voltage regulator; (C) as an oscillator.

Since glow lamps are, relatively, constant voltage devices, they may be used as gas diode voltage regulators in circuit (Fig. 3B) whose currents do not exceed the maximum lamp rating (Fig. 3B).

One of the most interesting uses for a glow lamp is as an oscillator (Fig. 3C). When connected in the familiar RC circuit shown in Fig. 3C, the lamp can be made to pulse or operate at frequencies ranging from one pulse in several seconds to frequencies well into the audio range.

For the very low frequency range it may be found better to connect the capacitor across the resistor, rather than across the lamp.

A glow lamp may be pulsed or caused to lock into a master oscillator by the use of a third electrode to which the input may be connected. This electrode may take the form of a conductive coat-

ing placed on the bulb or an external grid placed around the outside of the bulb.

Glow lamps are versatile devices. They are rugged, low in cost and require little current. It is felt that their unique features make them worthy of consideration in many applications, which fall within the scope of this organization.

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Including Schlieren and Cathode-Ray Oscilloscope Photography

Like its predecessor, which was published in the January 1951 *Journal* and *High-Speed Photography*, Vol. 3, this bibliography has been arranged in the following categories: General, Cameras, Lighting, Oscillography, Schlieren, Technical and Techniques, X-Ray.

The task of compiling the items was again undertaken by Miss Elsie Garvin, Librarian, Research Library, Eastman Kodak Co., Rochester, N.Y., and the bibliography was classified by John H. Waddell. It will be reprinted early in 1954 in Vol. 5 of *High-Speed Photography*.

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Flash Photography, R. Connolly, *Camera Mag., 76:* 49–66, Feb. 1953.

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Investigation of Annular Liquid Flow With Cocurrent Air Flow in Horizontal Tubes, A. E. Abramson, *J. Appl. Mech., 19:* 267–274, Sept. 1952.

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High-Speed Cine-Electrocardiography, J. J. Fields, L. Fields, E. Gerlach and M. Prinzmetal, *Jour. SMPTE, 59:* 493–497, Dec. 1952.

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The Electronic Camera in Film-Making, N. Collins and T. C. MacNamara, *Jour. SMPTE, 59:* 445–462, Dec. 1952.

Motion Photography for Combustion Research, F. W. Bowditch, *Jour. SMPTE, 59:* 472–484, Dec. 1952.

Accuracy Limitations on High-speed Metric Photography, A. E. Griffin and E. E. Green, *Jour. SMPTE, 59:* 485–492, Dec. 1952.

Application of High Speed Flash Tube to Photographing the Fundus of the Eye in Color, M. Jacobs and K. N. Ogle, *Rev. Sci. Instr., 24:* 52–55, Jan. 1953.

Flame Photography, R. B. Konikow, *Industrial Phot., 2:* 26–29, Jan. 1953.

Motion Picture and Flash Photography in Mechanics Research, C. C. Hauver, *PSA Jour.* (*Phot. Sci. Tech.*), *19B*, #1: 27–29, Feb. 1953.

High-Speed Photography in Medicine, J. H. Waddell, *PSA Jour.* (*Phot. Sci. Tech.*), *19B:* #1, 29–31, Feb. 1953.

Time-Resolved Spectroscopy of Ultraspeed Pellet Luminosity, W. A. Allen and E. B. Mayfield, *J. Appl. Phys., 24:* 131–133, Feb. 1953. (*Illustration of the single drum camera and spectrograph attachment, also a fast shutter and high-voltage switch arrangement.*)

High-Speed Photographic Techniques for the Study of the Welding Arc, I. L. Stern and J. H. Foster, *Jour. SMPTE, 60:* 400–404, Apr. 1953.

Use of Photography in the Underground Explosion Test Program, 1951–1952, R. M. Blunt, *Jour. SMPTE, 60:* 405–417, #4, Pt. 1, 1953.

Microsecond Photography of Rocket in Flight, E. Barkofsky, R. Hopkins and S. Dorsey, *Electronics, 26*: 142–147, June 1953. (*Electronically controlled flashlamps use in connection with 46 precision ballistics cameras.*)

Kinematographie von Gleitlinien auf Al-Einkristallen, R. Becker and P. Haasen, *Acta Metallurgica, 1:* 325–335, May 1953.

Photomicrography of Moving Specimens, B. A. Jarrett, *J. Phot. Sci., 1:* 97–108, May/June 1953.

Applications of High-Speed Photography in Rocket Motor Research, F. G. Stratton and K. R. Stehling, *Jour. SMPTE, 60:* 597–602, May 1953.

Combustion, F. T. McClure and W. G. Berl, *Ind. Eng. Chem.*, **45**: 1415–1425, July 1953. (*Contains illustrations of turbulent natural gas-air flame, and composite drum camera record of flame propagation in a tube containing a* **10%** *methane-air mixture.*)

Application of Image Converters to High Speed Photography, J. A. Jenkins and R. A. Chippendale, *J. Brit. Inst. Radio Eng., 11:* 505–517, Nov. 1951.

High Speed Photography: Steel Research Tool, R. A. Buchanan, *Steel, 131:* 90–91, July 7, 1952.

Ballistics Photography Uses, Mobile Flash, E. C. Barkofsky, *Electronics, 25:* 128–130, June 1952.

VII. X-RAY

The Applications of Radar Techniques to a System for High-Speed X-ray Motion Pictures, D. Dickson, C. Zavales and L. F. Ehrke, *Proc. Natl. Electronics Conf., 4:* 298–313, Nov. 1948.

X-Ray Motion Picture Techniques Employed in Medical Diagnosis and Research, S. A. Weinberg, J. S. Watson, Jr., and G. H. Ramsey, *Jour. SMPTE, 59:* 300–308, Oct. 1952.

X-Ray Motion Picture Camera and Printer for 70mm Film, S. A. Weinberg, J. S. Watson, Jr., and G. H. Ramsey, *Jour. SMPTE, 60:* 31–37, Jan. 1953.

Book Notes

Due to circumstances beyond our control the Society has been unable to obtain timely reviews of two high-speed photography books. The bibliographical data and contents are as follows:

The Photographic Study of Rapid Events

By W. D. Chesterman. Published (1951) by Oxford University Press, 114 Fifth Ave., New York 11, N.Y. 168 + i–xiii + 32 pp. plates. $4.25.

The book is divided into two parts, Part I covering "The Techniques Used" and Part II covering "The Application of the Techniques." Part I consists of the following chapter titles:

Ch. I — Classification of Techniques
Ch. II — Intermediate Rate Cameras
Ch. III — Lighting the Event
Ch. IV — Choice of Sensitive Material
Ch. V — Single Pictures
Ch. VI — Film Drum Cameras
Ch. VII — Spark and Schlieren Photography

Part II contains the following chapters:

Ch. VIII — Zoological Studies
Ch. IX — Biological and Medical Sciences
Ch. X — Physical and Engineering Research
Ch. XI — Military Applications
Ch. XII — Conclusion

High Speed Photography:
Its Principles and Applications

By George A. Jones. Published (1953) by John Wiley & Sons, 440 4th Ave., New York 16, N.Y. i–xvi + 311 pp. 118 illus. $5\frac{1}{4} \times 8\frac{1}{4}$ in. $4.50.

Ch. I — Introduction and History
Ch. II — The Production of Short Flashes
Ch. III — High Speed Cinematograph Camera Design
Ch. IV — Photographic Materials
Ch. V — High Speed Still Photography
Ch. VI — High Speed Cinematograph Cameras
Ch. VII — Cinematographic Technique
Ch. VIII — Trace Recording Cameras
Ch. IX — Picture-Making Recording Cameras
Ch. X — Scientific Applications of High Speed Photography
Ch. XI — Industrial and Commercial Applications
Appendixes A–C: High-Speed Cameras; Gas-Discharge Flash Tubes; Formulae

Engineering Activities

The number of projects in work, number and frequency of committee meetings and the attendance at these meetings are all useful clues to the volume of engineering work undertaken by the Society and to the relative importance to engineers and to the trade of results now being turned out. That this year's technical activities measure up on all counts will be attested to by the members of more than half the Society's engineering committees who attended some 25 hours of official meetings during the 74th Convention and thereby set some sort of record. Their accomplishments are briefly reviewed below.

Color: The scope of its two dormant subcommittees on (1) Projection Light Sources and Screens for Color Films, and (2) Spectral Energy Distribution of Photographic Illuminants was reviewed, and the decision was made to reactivate the subcommittees.

A new subcommittee was formed to prepare a color film exposure guide monograph for use by studio operating personnel.

Film Dimensions: This Committee was concerned primarily with 35mm film perforations for CinemaScope and decided to initiate standardization procedures. Material is now being assembled for a tentative standard and the committee would welcome any comments or questions from members and nonmembers alike.

Film Projection Practice: An energetic program of revising three existing standards was undertaken. These standards are: Projection Lenses for Motion Picture Theaters, Z22.28-1946; 35mm Projector Sprockets, Z22.35-1947; and Projector Reels for 35mm Film, Z22.4-1941. The scope of the latter standard is now being broadened to include both reels and magazines.

Films for Television: A small attendance permitted this group to have the distinction of being the only committee to meet in the RCA Coffee Club. Despite (or possibly because of) the informality, excellent coffee and buns, headway was made on two important projects: (1) Steps were taken to initiate standardization of the Society Synchronizing Leader. It is hoped that this leader will eventually be used both for theaters and television. (2) It was agreed to form a subcommittee to prepare the specifications and speed the development of a color television test film.

Laboratory Practice: This group continued its heavy standardization program. Letter ballots and draft standards on 16mm review-room screen brightness and on printer light change cuing are being or will shortly be circulated to the full committee. In addition, further action was recommended on revision of one standard, Sound Records and Scanning Area of 16mm Sound Motion Picture Prints, Z22.41-1946. Reaffirmation was recommended for two standards: Printer Aperture Dimensions for Contact Printing 16mm Positive Prints From 16mm Negatives, Z22.48-1946; and Printer Aperture Dimensions for Contact Printing 16mm Reversal and Color Reversal Duplicate Prints, Z22.49-1946.

Screen Brightness: Reports were heard from the four Subcommittees. The Subcommittee on Meters and Methods of Measurements was then disbanded since it had completed its assigned project (published in the October 1953 *Journal*). The question of 16mm review room screen brightness was also reviewed by this group and the same letter ballot will be circulated to both the Laboratory Practice and Screen Brightness Committees.

16mm and 8mm Motion Pictures: Revision of Z22.15-1946, and Z22.16-1947, 16mm Film Perforated One Edge — Usage in Camera and Projector, has been in the works for over a year, with the edge guiding question the only stumbling block. This question was thoroughly reviewed and a compromise solution was reached. This solution also affects the two standards on apertures, Z22.7-1950 and Z22.8-1950, where edge guiding is similarly involved. The chosen procedure is to delete the guided edge specification from all four standards and instead to prepare a Society Recommended Practice on the history, factors and trend in the edge guiding of 16mm film perforated one edge.

Revision of Z22.9-1946 and Z22.10-1947, 16mm Film Perforated Two Edges — Usage in Camera and Projector, has been stymied by another thorny question, the frame rate. It is fairly well agreed that the camera should run at nominally 16 frames/sec. The difference was primarily in part of the group insisting on a projector rate of 18 frames/sec and the other part wanting to retain a rate of 16 frames/sec. This question was not resolved; however, it was agreed that both groups would thoroughly document their positions in an effort to resolve the question at the next meeting, during the 75th Convention.

The proposed standard on a new Travel Ghost Test Film also came in for debate. Further action was tabled on this proposal until the committee has an opportunity to consider a counter proposal soon to be submitted by RCA.

Without controversy it was agreed: (1) to establish liaison with ASA Sectional Committee C81 on standardization of medium prefocus lamp sockets, (2) to investigate the possibility of the Society's producing a test film for 8mm projectors and (3) to form a subcommittee to study and possibly initiate standards on reels for television use, both in the 600-ft and over 2000-ft size.

Sound Committee: Discussion relating to standards was limited to two proposals: (1) 16mm Buzz Track Test Film, Z22.57-1947 — this was modified slightly and approved for further processing by the Standards Committee. (2) Magnetic Sound Specifications, 16mm Film Perforated Two Edges, SMPTE 626 — here the ±2-frame tolerance on the 26-frame separation of picture and sound was considered excessive and the proposal was returned to the Magnetic Recording Subcommittee for reconsideration.

The balance of the meeting was devoted to questions related to four-track stereophonic sound and required test films. Responsibility was assigned for drawing up manufacturing specifications for several types of four-track test films.

Magnetic Recording: This subcommittee of the Sound Committee recorded appreciable progress at this meeting. Agreement was reached on the common use of a 16mm Multifrequency Test Film supplied by the Society to determine the various projector sound-reproduce characteristics. It is expected that this will lead to the standardization of a common characteristic.

Two proposals on half-magnetic and half-photographic sound track, differing solely in the width of the magnetic stripe, had been under consideration. This was narrowed down to one (53-mil stripe) for letter ballot of the entire subcommittee.

A second draft of the proposal "200-mil Magnetic Sound Track on 16mm Film Perforated One Edge" was also approved for letter ballot.

Track placement and reproduce characteristics of four-track stereophonic sound was discussed and responsibility assigned for preparation of initial standards proposals.

Television Film Equipment: The principal purpose for calling this meeting was to resolve a conflict which had developed on one section of the 16mm Television Projector Standard, PH22.91. The disputed item concerned the length of the illumination pulse, whether the shutter pulse should be made 7% of the vertical blanking period or remain 5%. A compromise value of 6.5% was finally reached and found acceptable by all. With this question resolved, it will now be possible to continue processing of this standard in ASA Sectional Committee PH22.

Theater Engineering: The agenda was limited to consideration of a committee report providing an analysis of the Theater Screen Survey inaugurated by the committee in May 1953. The report, prepared by Ben Schlanger, Committee Chairman, was reviewed and the general outline approved after some modification. This report was subsequently presented to the Convention and will be published in a later issue of the *Journal.*

Stereoscopic Motion Pictures: Drafts of a bibliography and a nomenclature were reviewed. Both require additional work before publication is possible and plans were made to speed this activity. Two proposed standards were approved for letter ballot of the full committee. These specified: (1) the transmission characteristic of polarizing filters, and (2) where the left- and right-eye image lenses are not of exactly equal focal length, the longer focal length lens shall be used on the left-eye lens in all cases.—*Henry Kogel,* Staff Engineer.

Board of Governors Meeting

The Board on October 4 reviewed the Society's overall activities which are summarized in the Executive Secretary's report given below. Other matters and actions are here reported briefly:

After reports by Financial Vice-President Cahill and Treasurer Kreuzer and formal approvals of banking arrangements, attention was devoted to the Society's test film program services and expenses.

The name of the Test Film Quality Committee was changed to "Test Film Committee," and this Committee was charged with surveying the need for additional test films, and with reporting to the Engineering Vice-President on test film technical matters including suitability of all proposed new test film specifications and standards that originate within the other engineering committees.

E. S. Seeley, Secretary, advised the Board that the basic outline for the new Administrative Practices drawn up by Headquarters and Counsel had been submitted to him and that work was progressing. He also reported the results of the Society's national election for 1953. These and the Section's election results are given separately in this *Journal*.

J. W. Servies, Convention Vice-President, reported that plans for the 74th Convention had been completed. Registration fees, he said had been rescaled to favor members who would continue to pay \$5.00 weekly and \$2.00 daily fees, while nonmembers would be charged \$7.50 and \$2.50. Luncheon tickets were \$4.00 per person and tickets for the Cocktail Party-Banquet were \$12.50 per person, the same as charged at the 73d Convention.

A break from the custom of SMPTE award presentation during the midweek banquet of the fall convention each year had for some time been considered desirable by many members. As an attempt at a more appropriate setting for the award ceremony, the convention schedule was arranged with a formal awards session in place of the Monday night technical papers.

Exhibits, previously considered and carefully studied following the July meeting, were ruled out for the 74th Convention, by Mr. Servies, because time did not permit proper arrangement. Exhibits at subsequent conventions were discussed at length with a free expression of differing opinions, some favoring formal trade show exhibitions planned and managed by the Society, others opposing on the grounds that the theater equipment market was already well served by established shows, that television and electronics interests were ably satisfied by exhibitions of NARTB, IRE, National Electronics Conference, Radio-Parts show and the Audio Fairs, and that the areas of SMPTE interest not served thus far — laboratory equipment, specialized studio equipment and perhaps lighting equipment were all that would benefit. A suggestion that exhibits be held regularly with SMPTE Conventions was not approved.

Mr. Servies reported he had made plans to publish on Tuesday morning of convention week, a mimeographed list of Sunday and Monday registrants and that a supplement would be issued Wednesday.

The report of Engineering Vice-President Hood summarized the extensive engineering activities which are reflected in the reports and standards published continuously in the *Journal*. Standards approved by the Board of Governors will appear in the *Journal* as soon as they have ASA authorization.

Editorial Vice-President Simmons described program plans for the 74th Convention, and reported upon the current status of the *Journal*. Special plans for the 75th Convention were also reviewed, with information supplied by John Frayne, Chairman of the special committee for original plans for that Convention.

Gordon A. Chambers, Chairman of the Awards Study Committee, told of the approach taken by his group and of progress made to date. A draft of recommendations was submitted to individual Board Members for their study, with the request that reactions and suggestions be sent direct to Chairman Chambers for consideration by the Committee. The Board asked that this Committee include the Journal Award, this heretofore not having been formally included in the Committee's task. It is planned to publish the entire awards procedures as crystallized by this Committee in the April *Journal*.

Report of the Executive Secretary

Membership: New members admitted during the first nine months of 1953 reached 913, an all-time high. Delinquents, by the end of the same period, had been pushed down to the record low of 272. Net change for the period was 17 per cent. This is a net increase of 641 members, the best yet. There is an outside chance that the official year-end target, a net increase of 1000 members, will be reached.

Journal: The first nine *Journals* for 1953 contained six more pages than were published during the entire preceding year. Of these nine issues that add up to 1214 pages, three were in two parts. Part II for April was on magnetic striping, the second part for August covered screen brightness, and in the special issue for September, stereo sound was featured. Manuscripts now assured or on hand will fill three 125-page issues for October, November and December, each to contain a respectable subject grouping of articles. Contents for the two final months will have been derived primarily from the October convention. Because papers procurement efforts have continued to be very effective, additional "Part-two's" are planned for 1954.

Test Films: Quality control efforts by the Society's test film engineer continue to roll up a good record for the reliability of this valuable direct service to companies and individuals in both motion pictures and television. Demand for magnetic test films increases steadily. Present service, however, does not go far enough because the Society has had little success in finding suitable, reliable sources for some of the more essential 16mm films, but extensive efforts are being made to keep up with new film requirements without neglecting the ever increasing volume of requests for advice and technical assistance precipitated by the widespread adoption of new motion-picture and television techniques.

One special project now receiving attention is development of a special short version 16mm film for Navy projectionists. Early approval and volume production of the film during the fourth quarter are expected. Sales for the first three quarters lag 23% behind the target figure for the period and will doubtless be similarly behind at year end.

Engineering: The recent appearance of stereo sound and wide-screen and stereo picture systems has brought a pressing requirement for SMPTE attention to practical problems encountered in the installation and operation of these systems in theaters.

In addition, equipment people are seeking help with standards. This is also true in the field of 16mm motion pictures and magnetic recording. The most recent shifts of emphasis are reflected in the current list of items now being worked upon by committees and by the Headquarters staff.

One area long in need of attention but short on receipt of it is educational motion pictures. What of a practical nature can be done is not quite certain but the question must soon be cleared up so that SMPTE can answer a request for assistance that will shortly be forthcoming from NAVA.

Public Relations: A practical service to education of future motion-picture business and technical people is provided by SMPTE members who are active in the work of the USC Student Chapter, and by four in particular who took part in the National Conference of the University Film Producers Association held at USC in August. Another useful service was the Society's exhibit at the NAVA convention in Chicago.

Trade and daily press use of Society news releases has been both generous and sympathetic, but the Society has not sold itself effectively in all directions. Television is one publicity problem-area and those phases of our current work need further attention.

Another problem-area is exhibition. Although individual exhibitors or small-circuit owners may never develop an abiding interest in the Society, they should be well enough posted on how our work relates to exhibition so that recommendations, reports or standards that have theater application will find ready use.

New Officers

The results of the Society's election were announced at the Board of Governors Meeting on October 4, 1953, by Secretary Edward S. Seeley. The following were elected for two-year terms beginning January 1, 1954:

Axel G. Jensen, Engineering Vice-President
Barton Kreuzer, Financial Vice-President
Geo. W. Colburn, Treasurer
Frank N. Gillette, Governor, East
Lorin D. Grignon, Governor, West
Ralph E. Lovell, Governor, West
Garland C. Misener, Governor, East
Richard O. Painter, Governor, Central
Reid H. Ray, Governor, Central

In the Section elections, the following officers were elected for one-year terms, and new members of the Section Boards of Managers for two-year terms.

Atlantic Coast Section

John G. Stott, Chairman
Everett Miller, Secretary-Treasurer
George H. Gordon, Manager
George Lewin, Manager
J. Paul Weiss, Manager

Central Section

James L. Wassell, Chairman
Kenneth M. Mason, Secretary-Treasurer
Howard H. Brauer, Manager
George Ives, Manager
Henry Ushijima, Manager

Pacific Coast Section

Philip G. Caldwell, Chairman
Edwin W. Templin, Secretary-Treasurer
C. N. Batsel, Manager
Sidney Solow, Manager
Robert Young, Manager

Southwest Subsection

Ira L. Miller, Jr., Chairman
Walter W. Gilreath, Secretary-Treasurer
John H. Adams, Manager
Hervey Gardenshire, Manager
Hugh V. Jamieson, Sr., Manager
Donald Macon, Manager

Pacific Coast Section Meetings

Following a two-month summer hiatus, the Pacific Coast Section of the SMPTE met on September 22, 1953, at the Metro-Goldwyn-Mayer Pictures Studio in Culver City. The program subject for the evening was "3-D and Wide-Screen at M-G-M."

Because of the limited seating capacity on the sound stage at M-G-M, the attendance at the meeting had to be confined to two sessions allowing two hundred members each. Members were asked to telephone their reservations for attendance at the meetings, and were admitted by a show of membership card.

The program consisted of a presentation of 3-D and wide-screen techniques as they are being studied and used in production at a major Hollywood studio. An appraisal of the boxoffice value of the various new techniques and demonstrations from current productions made in Hollywood and England combined to make this an unusually timely and interesting program. Douglas Shearer, Director of Recording for M-G-M Pictures, lent invaluable assistance in planning the meeting. However, due to illness, Mr. Shearer was unable to attend, and Frank Milton, Mr. Shearer's assistant, presided for the evening. The film demonstrations of the engineering problems confronting the industry, as it considers CinemaScope, wide-screen, 3-D, different aspect ratios and stereophonic sound, were well planned and executed.

The meeting was particularly impressed by the thoroughness of M-G-M's policy in approaching the practical problem of triple-type theater film entertainment in the form of pictures in CinemaScope, wide-screen and 3-D in such a manner as to meet the maximum possible demand from the exhibitor. The excellent color quality of the daily rush prints reflected the progressive attitude in keeping in stride with latest color film developments.

There was an extensive and lively question and answer period after each of the two sessions.—*Philip G. Caldwell*, Secretary-Treasurer, Pacific Coast Section.

75th Semiannual Convention

Joe Aiken, Program Chairman for the 75th Convention at the Hotel Statler in Washington, D.C., May 3–7, has released a tentative roster of sessions based upon the special activities for this program, reported in the last *Journal.* Some papers have been added and technical sessions and, during a recent visit by Convention Vice-President Jack Servies, entertainment features were arranged according to hotel facilities. This is the tentative outline of the week's activities, subject to probable revision when the Author Forms are all in:

Monday Noon — Get-Together Luncheon
Monday Afternoon — "Professional 35mm Camera" by C. E. Phillimore
Monday Evening — "Black-and-White Cinematography" by C. E. K. Mees
Tuesday Morning — "35mm Projector" by R. Mathews and Willy Borberg
"The Evolution of Motion-Picture Theaters" by Ben Schlanger
Tuesday Afternoon — "Color Cinematography" by Gerald F. Rackett
Tuesday Evening — Pioneers' Dinner
Wednesday Morning — "Sound" by E. W. Kellogg
"Motion-Picture Lighting" by Charles W. Handley
Wednesday Afternoon — "16mm Camera and Projector" by Malcolm G. Townsley
Wednesday Evening — at the National Archives:
"Evolution of Motion-Picture Techniques" by James Card
"Matthew B. Brady" by Josephine Cobb
Thursday Morning — "Early Development of the 16mm Reversal Process" by Glenn E. Matthews and R. G. Tarkington
Thursday Afternoon — "The Motion-Picture Laboratory" by John I. Crabtree
Thursday Evening — Cocktail Hour and Dinner-Dance
Friday Morning — "The Photography of Motion" by Morton Sultanoff and John Waddell
"History of the Electronic Flash" by Harry Parker
Friday Afternoon — "Mechanical Television" by J. V. L. Hogan
"Electronic Television" by Axel G. Jensen

Most of the above papers will be about an hour in length. On each session there will be briefer papers about current developments in the industry, that is, the type of paper which usually makes up the substance of the program. The Papers Committee, listed in full in the November *Journal,* now has Author Forms and any member will welcome word about prospective papers.

Central Section Meeting

The Section held an all-day meeting on Friday, September 11, in Dayton, Ohio. At the morning session, which took place at Station WLW-D, Neal VanElls, Program Director of WLW-D, spoke on "TV Production Techniques," and Lester G. Sturgill, WLW-D's Chief Engineer, discussed "Problems in Transmission of Color TV."

For the afternoon session the meeting moved to the Wright Air Development Center, Air Research and Development Command, where two papers were read: "Electronic Viewer for Aerial Photographs," by Richard O. Eaton, Project Engineer of WADC-ARDC; and "16mm and 35mm Processing Equipment vs $9\frac{1}{2} \times 18\frac{1}{2}$ in. Processing Equipment," by R. D. Fullerton, Chief, Processing Equipment Section, WADC-ARDC. Members were given a demonstration of new reconnaissance equipment by means of stereo slides of terrain in Korea, and the reconnaissance equipment itself was available for inspection.

This program and facilities for it were arranged by Mrs. Jane Bernier, Synthetic Vision Corp., Dayton, Ohio.

Awards

The various honors awarded annually by the Society for outstanding achievements and contributions were presented during the Fall Convention in New York.

The general description of these awards, together with the names of all previous recipients, was published earlier this year, in the April *Journal*.

Journal Award

The Society's Journal Award, for the best paper published in the *Journal* during 1952, was shared by R. J. Spottiswoode, N. L. Spottiswoode and Charles Smith for their paper "Basic Principles of the Three-Dimensional Film" (October).

Honorable mention for outstanding papers was given to:

Willy Borberg, "Modulated Air Blast for Reducing Film Buckle" (August);

C. R. Carpenter and L. P. Greenhill, "A Scientific Approach to Informational-Instructional Film Production and Utilization" (May);

G. C. Higgins and L. A. Jones, "The Nature and Evaluation of the Sharpness of Photographic Images" (April);

Otto H. Schade, "Image Gradation, Graininess and Sharpness in Television and Motion-Picture Systems — Part II: The Grain Structure of Motion-Picture Images" (March); and

Norman Collins and T. C. MacNamara, "The Electronic Camera in Film-Making" (December).

Samuel L. Warner Memorial Award

W. W. Wetzel, of the Minnesota Mining and Mfg. Co., St. Paul, Minn., received the Samual L. Warner Memorial Award medal.

The citation for this award, read by Wallace V. Wolfe, Chairman of the Committee, was: "Dr. Wetzel has made recent noteworthy contributions to the development of excellent magnetic tapes and films now commercially available. Their improvement constitutes a step necessary to the widespread use of magnetic sound recording in the motion-picture industry."

David Sarnoff Gold Medal Award

Arthur V. Loughren, of the Hazeltine Corp., Little Neck, L. I., N. Y., was presented with the David Sarnoff Gold Medal Award by Loren L. Ryder, Chairman of the awarding committee. Mr. Loughren's service to the industry was cited as follows:

"For his contributions to the development of compatible color television including his active work on the principle of constant luminance adopted as part of the signal specifications of the National Television System Committee.

"For his participation in the work of the NTSC as Chairman of Panel 13, Color Video Standards.

"For his important contributions as a guiding spirit and forceful exponent of compatible color television, and for his simple mathematical expression and lucid description of the aims and accomplishments of the NTSC, prepared and published for the orientation of engineers working in that field."

Progress Medal

The Society's highest honor, the Progress Medal, was given to Fred Waller, President of Vitarama Company and Chairman of the Board of Directors of Cinerama, Inc., for "putting to practical use the peripheral vision phenomenon." David B. Joy, Chairman of the Progress Medal Award Committee, made the formal presentation and spoke of Fred Waller's work as follows:

"Fred Waller, in 1905, first entered the motion-picture field as a creator of lobby displays. From that time on, he has been deeply involved in the artistic and technical progress and development of the industry. His experiences include studio special effects, photographic research, optical printer design, and motion-picture production and direction. His interests cover other wide fields of endeavor. He has more than 50 patents ranging in diversity from optical printers to water skis.

"In 1938, just prior to the New York World's Fair, Waller organized a group for developing a concave screen process. For the Fair itself, he produced the motion pictures of the figures on the inside of the Perisphere and planned the Eastman Kodak Hall of Color demonstration. In fact, he built his first model of Cinerama hoping to sell it to one of the Fair's exhibitors, but his invention was considered too radical.

"He did apply this principle to the Waller Gunnery Trainer. This used five films projected simultaneously onto a spherical screen to show planes flying in imitation of battle conditions. This Trainer was used by the British and American Armed Forces and was said to have prevented thousands of casualties.

"Continuing in his faith that this curved screen process utilizing the effect of peripheral vision had entertainment value as well as utility in war, he set up a research laboratory on Long Island to continue his experiments.

"In 1946, he began to build the demonstration apparatus of the Cinerama process which he was to use in the public theater. Many new motion-picture tools had to be constructed for both taking and projecting simultaneously the three picture components. The screen itself was a special development made of overlapping strips of perforated plastic ribbon and spread over an arc of approximately 145°. His first private demonstration, staged in an indoor tennis court, was in 1949. This aroused great interest and controversy as to whether it would be as spectacular when viewed in a large theater.

"The finished product had its first public theater showing in September 1952. The reaction of the public is well known.

"Waller's work, and its reception by the public, has stimulated and intensified development, engineering and exploitation activity throughout the motion-picture industry. It has encouraged the industry and the public itself to look for and try out modifications in motion-picture photography and projection which had been thought heretofore too radical to consider.

"The Committee was unanimous in its decision that Fred Waller in his inventions, development and persistant faith in the possibilities of the peripheral vision phenomenon, has fully earned the recognition accorded him by this Award. This action of the Committee is in no way to be taken as an endorsement of any particular system of motion-picture presentation. It is a recognition of the accomplishments of the man himself and the tremendous catalytic effect on the rest of the industry."

New Fellows of the Society

On Wednesday evening, President Barnett inducted the following as new Fellows of the Society. The award was made posthumously to Kenneth Shaftan.

Merle H. Chamberlin, Metro-Goldwyn-Mayer Studios, Culver City, Calif.
LeRoy M. Dearing, Technicolor Motion Picture Corp., Hollywood, Calif.
Russell O. Drew, RCA Victor Division, Camden, N. J.
Carlos H. Elmer, U. S. Naval Ordnance Test Station, China Lake, Calif.
Frank N. Gillette, General Precision Laboratory, Pleasantville, N. Y.
Gerald G. Graham, National Film Board of Canada, Ottawa, Ontario, Canada
Sol Halprin, Twentieth Century-Fox Films, Los Angeles, Calif.
A. V. Loughren, Hazeltine Corp., Great Neck, N. Y.
Ralph E. Lovell, National Broadcasting Co., Los Angeles, Calif.

Arthur J. Miller, Consolidated Film Industries, Fort Lee, N.J.
John W. Servies, National Theatre Supply, New York, N.Y.
Kenneth Shaftan, J. A. Maurer, Inc., New York, N.Y.
Raymond J. Spottiswoode, Stereo Techniques, Ltd., London, England
Charles L. Townsend, National Broadcasting Co., New York, N.Y.
T. G. Veal, Eastman Kodak Co., Rochester, N.Y.

Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N. Y., at prevailing rates.

American Cinematographer

vol. 34, Aug. 1953

The Motion Picture Research Council 3-D Calculator (p. 373) *A. J. Hill*

3-D in Industrial Film Production (p. 374) *B. Howard*

Covering Spot News for Television (p. 378) *R. Renick*

vol. 34, Sept. 1953

A Stereo Camera for Two-Strip 16mm 3-D Photography (p. 428) *F. Foster*

Cinepanoramic—New French Anamorphic Lens (p. 434) *A. Rowan*

Wide Screen for 16mm Movies (p. 436) *J. Forbes*

Audio Engineering

vol. 37, Sept. 1953

A New Volume Visualizer (p. 30) *N. Prisament*

Handbook of Sound Reproduction. The Power Amplifier. Chapter 12, Pt. 3 (p. 36) *E. M. Villchur*

Bild und Ton

vol. 6, July 1953

Die Leistungsgrenzen der Fotoapparate (p. 195) *E. Hüttman*

Ein neuer Densograph (p. 212) *A. Erlenbach*

British Kinematography

vol. 23, July 1953

The Presidential Address (British Kinematograph Society) (p. 8) *B. Henri*

The Use of Film in Television Production (p. 13) *I. Atkins*

vol. 23, Aug. 1953

Process Projection in Colour

- Pt. 1. Introduction and Physical Aspects (p. 33) *R. L. Hoult*
- Pt. 2. The Preparation of Colour Plates for Still Projection (p. 36) *M. E. Harper*
- Pt. 3. Process Projection Equipment and Techniques Required for Colour Films (p. 38) *C. D. Staffell*

Some Notes on the British Standard of Screen Luminance (p. 43) *F. S. Hawkins*

Electronics

vol. 26, Oct. 1953

Television Monitors Rocket Engine Flame (p. 187) *F. A. Friswold*

Das Film-Technikum

vol. 4, Sept. 1953

Erste CinemaScope-Vorführung in Deutschland (p. 194)

Französisches Panoramaverfahren "Sonoptik" (p. 198)

"Wide Screen" verursacht Normenkrise (p. 199) *W. Gründorf*

Anamorphotische Optik für Kino-Breitschirmprojektion (p. 201)

Home Movies and Cine Photographer

vol. 20, Sept. 1953

16mm Wide Screen Available Now (p. 358)

Institution of Electrical Engineers, Proceedings

vol. 100, Pt. 1, Sept. 1953

Special Effects for Television Studio Productions (p. 288) *A. M. Spooner and T. Worswick*

International Photographer

vol. 25, Sept. 1953

Dark Thoughts on the New (p. 5) *J. T. de Kay*

16mm 3-D Camera (p. 8) *F. A. Parrish*

The Superscreen is Here to Stay (p. 12) *C. W. Dudley*

International Projectionist

vol. 28, Aug. 1953

Stereoscopic Projection and Photography (p. 5) *R. A. Mitchell*

Converting Theatres for CinemaScope (p. 11)

vol. 28, Sept. 1953

Does CinemaScope Have the Answer? (p. 5) *T. L. Burnside*

Stereoscopic Projection and Photography (p. 9) *R. A. Mitchell*

Color TV...and How it Works! (p. 14) *J. Morris*

How to Check for—and Get—Maximum Light at the Screen (p. 16)

Motion Picture Herald

vol. 193, Oct. 10, 1953

Theatre Built for 3-D and Wide-Screen (p. 14)

Sizing the Picture for "Wide-Screen" (p. 16) *B. Schlanger*

Functional Lighting of Auditoriums (p. 20) *S. McCandless*

Philips Technical Review

vol. 15, No. 1, July 1953

A Large-Screen Television Projector (p. 27) *J. Haantjes and C. J. van Loon*

Photo-Technik und Wirtschaft

vol. 4, Oct. 1953

Exakte oszillographische Messungen der Arbeitsweise von Kamera-Synchronkontakten (p. 392) *J. Czech*

Radio and Television News (Radio-Electronic Engineering Edition)

vol. 50, Sept. 1953

Visual Proof of Performance Measurements (p. 14) *R. D. Chipp*

Looking at Tubes. Picture Reproducing Tubes for Color Television (p. 22) *W. B. Whalley*

RCA Review

vol. 14, Sept. 1953

A VHF-UHF Television Turret Tuner (p. 318) *T. Muramaki*

A Comparison of Monochrome and Color Television with Reference to Susceptibility to Various Types of Interference (p. 341) *G. L. Fredendall*

Technical Signal Specifications Proposed as Standards for Color Television (p. 359)

Tele-Tech

vol. 12, Sept. 1953

Final NTSC Color TV Standards (p. 63)

Magnetic Recording (p. 81) *M. Camras*

vol. 12, Oct. 1953

Flexible TV Studio Intercom System (p. 79) *R. D. Chipp and R. F. Bigwood*

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 MEMBERSHIP DIRECTORY.

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Aspaas, S. J., Salesman, National Theatre Supply, 1961 South Vermont Ave., Los Angeles 7, Calif. (**A**)

Aufhauser, Fred E., Manufacturer, Projection Optics Co., Inc., Rochester, N.Y. (**A**)

Bass, Robert, Film Producer, Bass Films, Inc. **Mail:** 923 Fifth Ave., New York, N.Y. (**M**)

Berk, Milton, Chief Projectionist, Capitol Theatre. **Mail:** 492 Oakdene Ave., Ridgefield, N.J. (**M**)

Bower, Wilford W., Technical Representative, W. J. German, Inc., John St., Ft. Lee, N.J. (**A**)

Brewer, W. Lyle, Supervisor, Physical Standards and Services Section, Color Technology Division, Eastman Kodak Co. **Mail:** 275 Sagamore Dr., Rochester, N.Y. (**A**)

Brooks, William N., Executive Vice-President, In Charge of Production, McGeary-Smith Laboratory. **Mail:** 2K Northway, Greenbelt, Md. (**A**)

Brush, John M., Electronic Engineer, A. B. DuMont Laboratories, Inc. **Mail:** 35 Belmont Ave., Clifton, N.J. (**M**)

Burgess, George, Sound Supervisor, Alliance Film Studios, Ltd. **Mail:** Flat 6, 72 Notting Hill Gate, London, W. 11, England. (**A**)

Burns, Robert E., Technical Consultant, W. J. German, Inc. **Mail:** 2340 Linwood Ave., Fort Lee, N.J. (**A**)

Cameron, Donald F., Television Engineer, Storer Broadcasting Co., (WSPD-TV). **Mail:** 1619 Milburn Ave., Toledo 6, Ohio. (**A**)

Cedrone, Nicholas J., Mechanical Engineer, Artisan Metal Products, Inc., 73 Pond St., Waltham 54, Mass. (**A**)

Chambers, Maude L., Art Programs for Color TV. **Mail:** 1901 Jackson St., Amarillo, Tex. (**M**)

Chapman, Christopher M., Film Producer. **Mail:** 293 Roxborough St., East, Toronto, Ontario, Canada. (**A**)

Clark, Thomas C., Jr., Electrical Engineer, Hughes Aircraft Co. **Mail:** 5381 Village Green, Los Angeles 16, Calif. (**M**)

Cope, Gerald B., Mechanical Engineer, AFMTC, Technical Systems Laboratory, Patrick Air Force Base. **Mail:** 58 Vesta Circle, Melbourne, Fla. (**M**)

Dougherty, Joseph T., Salesman, Raw Stock Sales, E.I. du Pont de Nemours & Co., Inc., 248 W. 18 St., New York, N.Y. (**M**)

Elms, Charles D., Motion-Picture Producer. **Mail:** 163 Highland Ave., North Tarrytown, N.Y. (**M**)

Evenden, W. Lewis, Television Engineer, WMBR-TV. **Mail:** 22—10 Ave., North, Jacksonville Beach, Fla. (**M**)

Getze, Walter F., Television Engineer, KLAC-TV. **Mail:** 198 South Commonwealth Ave., Los Angeles, Calif. (**M**)

Gubbins, L. J., Sound Recording Engineer, Compania Shell de Venezuela Ltd., Apartados 809, Caracas, South America. (**A**)

Hanley, Francis Xavier, Broadcasting and Television Studio Engineer, Bremer Broadcasting Corp. **Mail:** 647 E. 14 St., New York. (**M**)

Hayes, John D., Optical Engineer, Bausch & Lomb Co., Rochester 2, N.Y. **(M)**

Hazard, S. J., Importer, A. Hazard Co. **Mail:** 7 Lexington Ave., New York 10, N.Y. **(A)**

Heinzman, Lewis C., Radio-Television Engineer, McClatchy Broadcasting Co. **Mail:** 1930 Seventh Ave., Sacramento, Calif. **(A)**

Huether, George F., Television Studio Technical Supervisor, U.S. Navy Special Devices Center. **Mail:** 95 Falmouth Pl., Albertson, Long Island, N.Y. **(A)**

Hughes, John F., Film Editor, Movietonews, Inc., 460 W. 54 St., New York, N.Y. **(M)**

Jacobs, George, Television Engineer, National Broadcasting Company. **Mail:** 1802 E. 21 St., Brooklyn 29, N.Y. **(M)**

Jansen, Paul W., Sales Manager, Minnesota Mining & Manufacturing Co., 900 Fauquier Ave., St. Paul, Minn. **(M)**

Jansky, C. M., Jr., Radio and Electronic Engineer, Jansky & Bailey, Inc., 1339 Wisconsin Ave., N.W., Washington, D.C. **(M)**

Kivell, Donald W., Head, Camera & Stage Branch, U.S. Naval Photographic Center. **Mail:** 120 East Hunting Towers, Alexandria, Va. **(A)**

Kooser, H. L., Director, Visual Instruction Service, Iowa State College, Ames, Iowa. **(A)**

Kyburz, L. C., Director of Physical Properties, Jefferson Amusement Co. **Mail:** 2685 Hazel St., Beaumont, Tex. **(M)**

Landry, Robert William, Chief, Training Film Unit, NSA Defense Dept. **Mail:** 25 Southdown Rd., Alexandria, Va. **(A)**

Lavin, Thomas, Motion-Picture Printer, Signal Corps Pictorial Center. **Mail:** 332—42 St., Brooklyn, N.Y. **(A)**

Lindgren, Emanuel O., Equipment Inspector, Arabian American Oil Co., Box 1011, Dhahran, Saudi Arabia. **(A)**

Lindow, Walter, Sound Engineer, General Theatre Supply Co., Ltd. **Mail:** Apt. 8, 31 South St., Halifax, Nova Scotia. **(A)**

Lohse, Karl-Heinz, Microscopist and Photographer, Marathon Corp., Menasha, Wis. **(A)**

Lomas, Stanley A., Advertising Vice-President, Director, TV Commercial Dept., Wm. Esty Co., 100 E. 42 St., New York, N.Y. **(M)**

MacAdam, David L., Research Physics, Eastman Kodak Co., Kodak Park Works, Rochester 4, N.Y. **(A)**

Madery, Earl M., Sound Technician RCA Victor Division. **Mail:** 4847 Alonzo Ave., Encino, Calif. **(A)**

Markley, Charles W., Engineer, Pathe Laboratories, 6823 Santa Monica Blvd., Los Angeles, Calif. **(A)**

Midorikawa, Michio, Technical Supervisor, Daiei Motion Picture Co. **Mail:** 1262, Noborito-cho, Kawasaki-city, Kanagawa-ken, Japan. **(M)**

Miller, Albert Robert, Sensitometrist, Color Corporation of America, 2800 West Olive, Burbank, Calif. **(A)**

Miller, Franklin C., Engineer, Fairchild Aerial Surveys, Inc. **Mail:** 3635 Kalsman Dr., Los Angeles 6, Calif. **(A)**

Mills, Kenneth N., Motion-Picture Production Technician, U.S. Government. **Mail:** 2210 Emerson Ave., Apt. 5, Dayton 6, Ohio. **(A)**

Minter, Jerry B., Radio Engineer, Measurements Corp. **Mail:** Box #1, Boonton, N.J. **(M)**

Mitchell, Hubert R., Manufacturer, Hubert Mitchell Industries, Inc., Box 690, Hartselle, Ala. **(M)**

Nagel, George A., Plant Superintendent, Consolidated Film, Main St., Ft. Lee, N.J. **(M)**

Peque, Raymond, Motion-Picture Projectionist, Supervisor of Shipbuilding, U.S. Navy. **Mail:** 65 Liberty St., Lodi, N.J. **(A)**

Rauenbuhler, Robert L., Engineering Technician U.S.N.S.R.&D.F., Naval Supply Depot. **Mail:** 10 Nesbitt St., Jersey City, N.J. **(A)**

Reeves, James J., Television Engineer, Columbia Broadcasting System. **Mail:** 1515 Metropolitan Ave., Apt. 4B, New York 62, N.Y. **(M)**

Rejlek, Frank X., Assistant to Producer, Gene Lester Productions. **Mail:** 10702 Holman Ave., Los Angeles 24, Calif. **(M)**

Seibel, Martin, Operator of Film Service, M. Seibel Film Service, Box 625, Industrial Branch, Hillside, N.J. **(A)**

Sorem, Allan L., Research Physicist, Research Laboratories, Eastman Kodak Co., Kodak Park, Rochester, N.Y. **(M)**

Tourangeau, Raymond G., Sales Supervisor, Ansco, 247 East Ontario St., Chicago, Ill. **(A)**

Wilkie, James W., President, Continental Machines, Inc., Savage, Minn. **(A)**

Wright, Harry G., Mechanical Engineer, Television Projectors, RCA Victor Division, Dept. 587, Bldg. 10-3, Camden, N.J. **(M)**

CHANGES IN GRADE

Wells, Thomas H., (A) to (M)
Shamberg, Kurt D., (S) to (A)

DECEASED

Kral, Karel B., Director, Manager, Griffin Film Enterprises, Griffin Lodge, Betsham, North Gravesend, Kent, England. **(M)**

Employment Service

These notices are published for the service of the membership and the field. They are inserted or three months, at no charge to the member. The Society's address cannot be used for replies.

Position Wanted

Motion-Picture Television Technician: 10 yr intensive skill and know-how related to 16-35mm cinematography, animation, recording (optical, tape, disk), editing, laboratory processing practice (black-and-white, color); also kinescope recording techniques; self-reliant; inventive; relocate if required; write: CMC, Technical Associates, 60 East 42d St., New York 17, N.Y.

Positions Available

Wanted: Sound Engineer for New York film production studio, operation and maintenance on optical and magnetic sound equipment; electronics background essential. Send résumé to R. Sherman, 858 West End Ave., New York, N.Y.

Technical Photographer, age 27 to 38, for senior position with large California industrial research organization. Should be conversant with contemporary techniques for recording data; acquainted with microscopy, graphic arts and color processes. Job involves application of photographic techniques as experimental tool in research projects. Administrative experience helpful. Excellent career opportunity for an ingenious and inventive person. Retirement pension and other benefit plans. Application held in strict confidence. Write giving personal data, education and experience to Henry Helbig and Associates, Placement Consultants, Examiner Bldg., 3d and Market Sts., San Francisco 3, Calif.

Sound Engineer: Complete responsibility for sound control, including printing, processing, maintenance of standards, etc. Tri Art Color Corp., 245 West 55th St., New York 19, N.Y.

Motion-Picture Supervisor, GS-8: Duties as Chief of Motion Picture Section to include all phases of aeromedical research cinematography. Experience in planning, directing, lighting, color control, recording in single or double-system sound. Laboratory work requires experience with sensitometric control equipment, contact printers, automatic processors, Moviola, sound synchronization equipment, titlers, etc. For detailed information write: Photography Officer, USAF School of Aviation Medicine, Randolph Field, Texas.

Motion-Picture Sound Transmission Installer and Repairer, for the Signal Corps Pictorial Center, Long Island City, N.Y.—one at \$2.59/hr; one at \$2.29/hr (40-hr week). Applicants for \$2.29/hr position must have had 4½ yr progressively responsible experience in the construction, installation and maintenance of electronic equipment, of which at least 1½ yr must have been in the specialized field of motion-picture film, disk or magnetic sound recording or reproducing equipment. Applicants for \$2.59/hr position must have had at least 5 yr responsible experience in the design, development and installation of electronic equipment, of which at least 2 yr must have been in the specialized field of motion-picture film, disk or magnetic sound recording or reproducing equipment. Must be familiar with filter design and transmission testing, involving the use of a wide variety of testing and measuring devices. Each year of study successfully completed in a residence school above high school level in electrical, electronic or radio engineering, may be substituted for the general, but not the specialized experience indicated above, at the rate of one scholastic year for each 9 mo. of experience. All applicants must be familiar with Western Electric and RCA systems. Obtain Form SF 57 at any first class Post Office or Government Agency; forward or bring completed form to Civilian Personnel Division, Signal Corps Pictorial Center, 35–11 35th Ave., Long Island City, N. Y.

New Membership Directory

At the first of this month, dues bills went to members in the United States, with a return envelope bearing a clipping of their 1952 Membership Directory listing. Earlier, the same was sent to members outside the United States. The returned and corrected clippings will be the basis for a new directory, scheduled to be Part II of the April *Journal*.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April *Journal*.

Papers Presented
at the New York Convention, October 5–9

MONDAY NOON—Get-Together Luncheon

MONDAY AFTERNOON—Basic Principles—Stereophony and Stereoscopy

W. B. Snow, Consultant in Acoustics, Los Angeles, Calif., "Basic Principles of Stereophonic Sound."

D. L. MacAdam, Eastman Kodak Co., Rochester, N.Y., "Stereoscopic Perceptions of Size, Shape, Distance and Direction."

TUESDAY MORNING (Concurrent Sessions)
————Equipment for Stereophonic Sound Reproduction

C. C. Davis and H. A. Manley, Westrex Corp., Hollywood, Calif., "An Auxiliary Multitrack Magnetic Sound Reproducer."

J. D. Phyfe, RCA Victor Division, Camden, N.J., and C. E. Hittle, RCA Victor Division, Hollywood, Calif., "A Film-Pulled, Theater-Type, Magnetic Sound Reproducer for Use With Multitrack Films."

S. W. Athey, Willy Borberg and R. A. White, General Precision Laboratory, Inc., Pleasantville, N.Y., "A Four-Track, Magnetic Theater Sound Reproducer for Composite Films."

J. K. Hilliard (Moderator), Altec Lansing Corp., Los Angeles, Calif., Panel Discussion on "Equipment for Stereophonic Sound Reproduction."

————High-Speed Photography Session

John H. Waddell, Wollensak Optical Co., Rochester, N.Y., "Critique of High-Speed Photography Demonstration Films."

J. S. Watson, Jr., S. A. Weinberg and G. H. Ramsey, University of Rochester School of Medicine and Dentistry, Rochester, N.Y., "Stereoscopic X-Ray Motion Pictures."

H. M. Ferree, General Electric Co., Nela Park, Cleveland, Ohio, "Glow-Lamps in High-Speed Photography and Related Applications."

Peter Carey, K. C. Halliday and F. B. Terry, Eclipse-Pioneer, Division Bendix Aviation Corp., Teterboro, N.J., "High-Speed Photography of Flame Initiation Phenomena."

Isaac S. Goodman, Westinghouse Electric Corp., Lamp Division, Bloomfield, N.J., "Application of High-Speed Motion-Picture Photography to Quality and Processes Analysis in the Lamp Industry."

R. W. Nottorf and W. H. Vinton, E. I. du Pont de Nemours & Co., Inc., Photo Products Division, New York, "New Reversal Film Suitable for Normal or Rapid Processing."

John H. Waddell (Moderator), Wollensak Optical Co., Rochester, N.Y., "Open Forum on High-Speed Photography."

TUESDAY AFTERNOON—Laboratory Practices Session

A. A. Rasch and J. I. Crabtree, Kodak Research Laboratories, Rochester, N.Y., "Development of Motion-Picture Positive Film by Vanadous Ion."

Samuel R. Goldwasser, Signal Corps Pictorial Center, Long Island City, N.Y., "A Mathematical Approach to Replenishment Techniques."

A. H. Vachon, National Film Board of Canada, Ottawa, Ontario, Canada, "Stainless-Steel Developing-Machine Rollers."

Walter R. J. Brown, Eastman Kodak Co., Rochester, N.Y., "A Rapid Scanning Microdensitometer."

TUESDAY EVENING—Armed Forces—Foreign-Language Conversions

Thomas Baird, United Nations Headquarters, New York, "International Film Audience."

Otto Rauhut, Condor Films, Inc., St. Louis, Mo., "Direct-Positive Variable-Density Recording Utilizing Supersonic Bias With Galvanometer-Type Light Modulator."

Max G. Kosarin, Signal Corps Pictorial Center, Long Island City, N.Y., "Preparation of Foreign Language Versions of U.S. Army Films."

George Lewin, Signal Corps Pictorial Center, Long Island City, N.Y., "Magnetically Striped Loops for Lip-Synchronizing Production."

J. C. Greenfield, U.S. Naval Photographic Center, Anacostia, D.C., "Language Conversion, Other Applications; Using a Special 16mm Magnetic Projector-Duplicator."

E. W. D'Arcy, DeVry Corp., Chicago, Ill., "A Film-Exchange Foreign-Language Conversion Equipment."

WEDNESDAY MORNING—Television Film Reproduction, Color and Monochrome

R. G. Neuhauser, RCA Tube Department, Lancaster, Pa., "Vidicon Camera Tube for Film Pickup."

H. N. Kozanowski, RCA Victor Division, Camden, N.J., "Vidicon Film-Reproduction Cameras."

Warren R. Isom, RCA Victor Division, Camden, N.J., "A Fast-Cycling Intermittent for 16mm Film."

Raymond W. Wengel, Camera Works, Eastman Kodak Co., Rochester, N.Y., "A Pneumatic Pulldown 16mm Projector."

Ernest H. Traub, Philco Corp., Philadelphia, Pa., "New 35mm Television Film Scanner."

V. Graziano and Kurt Schlesinger, Motorola, Inc., Chicago, Ill., "A Continuous All-Electronic Scanner for 16mm Color Film."

WEDNESDAY AFTERNOON—Television—Theater, Recording, Lighting

F. A. Cowan, American Telephone and Telegraph Co., New York, "Networks for Theater Television."

D. J. Parker, S. W. Johnson and L. T. Sachtleben, RCA Victor Division, Camden, N.J., "Apparatus for Aperture-Response Testing of Large Schmidt-Type Projection Optical Systems."

R. M. Fraser, National Broadcasting Co., New York, "A New 35mm Single-Film-System Kinescope Recording Camera."

William R. Ahern, National Broadcasting Co., New York, "Television Lighting Routines."

THURSDAY AFTERNOON—Color and Black-and-White Reproduction

H. H. Schroeder and A. F. Turner, Bausch & Lomb Optical Co., Rochester, N.Y., "Primary Color Filters With Interference Films."

Ralph M. Evans and W. Lyle Brewer, Eastman Kodak Co., Rochester, N.Y., "The First and Second Black Conditions."

C. R. Anderson, C. E. Osborne, F. A. Richey and W. L. Swift, Eastman Kodak Co., Rochester, N.Y., "Sensitometry of the Color Internegative Process."

A. L. Sorem, Eastman Kodak Co., Rochester, N.Y., "The Effect of Camera Exposure on the Tone Reproduction Quality of Motion Pictures."

THURSDAY EVENING—Three-Dimensional Film Equipment and Practices

Chester E. Beachell, National Film Board of Canada, Ottawa, Canada, "A 35mm Stereo Cine Camera."

R. Clark Jones and W. A. Shurcliff, Polaroid Corp., Cambridge, Mass., "Equipment to Measure and Control Synchronization Errors in 3-D Projection."

W. A. Shurcliff, Polaroid Corp., Cambridge, Mass., "Screens for 3-D and Their Effect on Polarization."

L. W. Chubb, D. S. Grey, E. R. Blout and E. H. Land, Polaroid Corp., Cambridge, Mass., "Properties of Polarizers for Filters and Viewers for 3-D Motion Pictures."

A. J. Cardile and J. J. Hoehn, RCA Victor Division, Camden, N.J., "New Portable 16mm Arc Projector Adapted for 3-D Projection."
Raphael G. Wolff, Wolff Studios, Hollywood, Calif., "Three-Dimensional Films for Business and Industry."

FRIDAY MORNING—Recent History of New Techniques—Wide-Screen Methods

Ben Schlanger (Committee Chairman), Theater Consultant, New York, "Theater Screen Survey."
Ralph H. Heacock, RCA Victor Division, Camden, N.J., "Practical Application of New Motion-Picture Techniques Introduced in Theaters During the Past Year."
Fred Waller, Cinerama, Inc., New York, "The Cinerama Process."
John D. Hayes, Bausch & Lomb Optical Co., Rochester, N.Y., "CinemaScope Optics."
Edgar Gretener, Dr. Edgar Gretener, A.G., Zurich, Switzerland, "An Improved Carbon-Arc Light Source for Three-Dimensional and Wide-Screen Projection."
C. E. Greider, National Carbon Co., Cleveland, Ohio, "Performance of High-Intensity Carbons in the Blown Arc."

FRIDAY AFTERNOON—General Session

M. A. Hankins and Peter Mole, Mole-Richardson Co., Hollywood, Calif., "Recent Development of a Compact High-Output Engine-Generator Set for Lighting Motion-Picture and Television Locations."
R. J. Youngquist and W. W. Wetzel, Minnesota Mining & Mfg. Co., St. Paul, Minn., "Ferrite-Core Heads for Magnetic Recording."
J. K. Hilliard (Committee Chairman), Altec Lansing Corp., Los Angeles, Calif., "Sound Committee Report."
J. G. Frayne (Moderator), Westrex Corp., Hollywood, Calif., Panel Discussion on "Magnetic Head Wear."

Meetings

American Institute of Electrical Engineers, Winter General Meeting, Jan. 18–22, 1954, New York
National Electrical Manufacturers Assn., Mar. 8–11, 1954, Edgewater Beach Hotel, Chicago, Ill.
Radio Engineering Show and I.R.E. National Convention, Mar. 22–25, 1954, Hotel Waldorf Astoria, New York
Optical Society of America, Mar. 25–27, 1954, New York
The Calvin Eighth Annual Workshop, Apr. 12–14, 1954, The Calvin Co., Kansas City, Mo.
Society of Motion Picture and Television Engineers, Central Section, Spring Meeting, Apr. 15, 1954, The Calvin Co. Sound Stage, Kansas City, Mo.
75th Semiannual Convention of the SMPTE, May 3–7, 1954, Hotel Statler, Washington
American Institute of Electrical Engineers, Summer General Meeting, June 21–25, 1954, Los Angeles, Calif.
Acoustical Society of America, June 22–26, 1954, Hotel Statler, New York
Illuminating Engineering Society, National Technical Conference, Sept. 12–16, 1954, Chalfonte-Haddon Hall, Atlantic City, N.J.
Photographic Society of America, Annual Meeting, Oct. 5–9, 1954, Drake Hotel, Chicago, Ill.
American Institute of Electrical Engineers, Fall General Meeting, Oct. 11–15, 1954, Chicago, Ill.
76th Semiannual Convention of the SMPTE, Oct. 18–22, 1954 (next year), Ambassador Hotel, Los Angeles
77th Semiannual Convention of the SMPTE, Apr. 17–22, 1955, Drake Hotel, Chicago
78th Semiannual Convention of the SMPTE, Oct. 3–7, 1955, Lake Placid Club, Essex County, N.Y.

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